Design Opportunities in Reducing Domestic Food Waste: A Collective Approach

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PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Technische Universiteit Eindhoven, op gezag van de rector magnificus prof.dr.ir. F.P.T. Baaijens, voor een commissie aangewezen door het College voor Promoties, in het openbaar te verdedigen op 29 maart 2017 om 16:00 uur.

door

Veranika Lim

geboren te Jakarta, Indonesië

Dit proefschrift is goedgekeurd door de promotoren en de samenstelling van de promotiecommissie is als volgt:

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1e promotor:	prof.dr. G.M.W. Rauterberg
2e promoter:	prof.dr.ir. C. Regazzoni (Università degli Studi di Genova)
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	dr. L. Marcenaro (Università degli Studi di Genova)
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GRATITUDE

Like any other child, my parents and family had to ask me constantly to finish the rice on my plate. Otherwise it would suffer and cry, they would say. Like any other child, I did not understand the actual consequences of food waste. I was likely confused. It was not until later that I found more convincing reasons for finishing my plate, and for caring more for our environment and humanity. My appreciation for what nature can give us, the mountains, and the sea, brought me back to that same moment when I was a child, this time with the ability to find out why I should finish my plate. The lack of understanding and curiosity lead me to the writing of this work. And I am immensely grateful for those who have supported me along this journey.

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Veranika
Jakarta, January 2017

*"Human beings don't have a pollution problem:
they have a design problem."*

William McDonough and Michael Braungart
in *The Upcycle*.

I believe this also applies to the global issue on food waste.

CONTENTS

FOREWORD

In its "Definitional Framework of Food Loss and Waste" (June 2016), the Food and Agriculture Organization of the United Nations (FAO) has made a distinction between food loss and food waste. Food loss (FL) in the production to distribution segments of the food supply chain (FSC) is mainly caused by the functioning of the food production and supply system or its institutional and legal framework. Food waste (FW) refers to the removal of food from the FSC which is fit for human consumption, by choice, or which has spoiled or expired, mainly caused by economic or social behavior, poor stock management or neglect. The difference between FL and FW is not always sharply defined. However, the distinction is made because the underlying reasons, economic framework and motivation of the FSC actors for wasting food are very different from the unintended food loss, and subsequently the strategies on how to reduce food waste are conceived in a different, targeted manner. The reasons for food waste by consumer households is mostly related to peoples attitude, behavior and awareness. Why should we care if people who can afford it throw away good food? Apart from the ethical aspect of it in a world where hundred of millions go hungry, in recent years it has become clear that the level of production, storage and distribution of food that is not eaten constitutes a *significant* contribution to the negative impacts of climate change. Not producing what is not used or needed should be the *most direct, economic and efficient way* to reduce the industrial impact on climate change. Food waste reduction is, however, extremely complicated because it is a multi-dimensional problem. The causes and solutions to the problem have technical, economic, environmental, social, behavioral, ethical, legal and political aspects. This means that all actors in the food systems need to work together to effectively address the issue. Currently the political and institutional awareness of the food waste problem is well established. Worldwide research is being conducted and action is being taken to measure food waste, to develop solutions for food waste reduction, and to raise awareness among the actors in the food supply chains and the consumers. Making people aware is one thing, but making them to change their habits is an entirely different problem. Therefore, we very much welcome this work, because in a unique way it directly connects awareness raising to behavior change, with the aim of effective food waste reduction, and as such it provides a basis for further research and implementation of workable solutions in real life.

Robert van Otterdijk
Global Initiative on Food Loss and Waste Reduction - Save Food
Food and Agriculture Organization of the United Nations (FAO)

1 INTRODUCTION

The impact of food waste on the environment and food security has become a global concern. Previous estimates show that one-third to one-half of the world's food, approximately 1.3 billion tonnes, becomes waste (Gustavsson et al., 2011). This goes hand in hand with the overconsumption of natural resources: food waste produces 10 percent of rich countries greenhouse gas emissions and is responsible for the use of 550 billion cubic meters of water globally (Stuart, 2013). Despite these numbers, twice as much food is globally produced than required by nutritional needs per living person (Fox Cheng, 2013). In fact, with less than a quarter of the food we waste, the world's nearly one billion hungry people could be lifted out of undernourishment. If we continue current consumption patterns, food production would need to increase by 70 percent to feed all 9 billion people in 2050[1]. These global facts show that food waste should receive critical attention.

1.1 THE ROLE OF CONSUMERS

Food waste occurs at all stages of the food supply chain in all countries. Whilst in low-income countries, over 80 % of food waste is generated at post-harvest and processing levels, in high/medium-income countries, about 40% of food waste is generated at retail and consumer levels (See figure 1) (Gustavsson et al., 2011; Beretta et al., 2013). Consumers in high/medium-income countries generate waste (222 million tons) that is almost as high as the total net food production (230 million tons) in Sub-Saharan Africa (Gustavsson et al., 2011). Buzby and Hyman (2012) conducted a study in the United States showing that 19 percent of the total amount of consumers' food supply gets wasted. Likewise, Quested and Johnson (2009) conducted a study in the United Kingdom showing that 21.3 percent of the purchases ends up in the bin. These studies prove that consumers are important drivers of overall waste generation, resource consumption, and impacts on the environment (IPCC, 2007). If we only reduce food waste in Europe at the consumer level, we could impact Gross Domestic Product (GDP) increase and land use in Europe, as well as food security in Sub-Saharan Africa (Rutten, 2013).

How much a consumer waste was found to be related with the type of consumer (Wrap, 2008). Wrap showed that households in which the respondents were aged

1 http://www.eu-fusions.org/

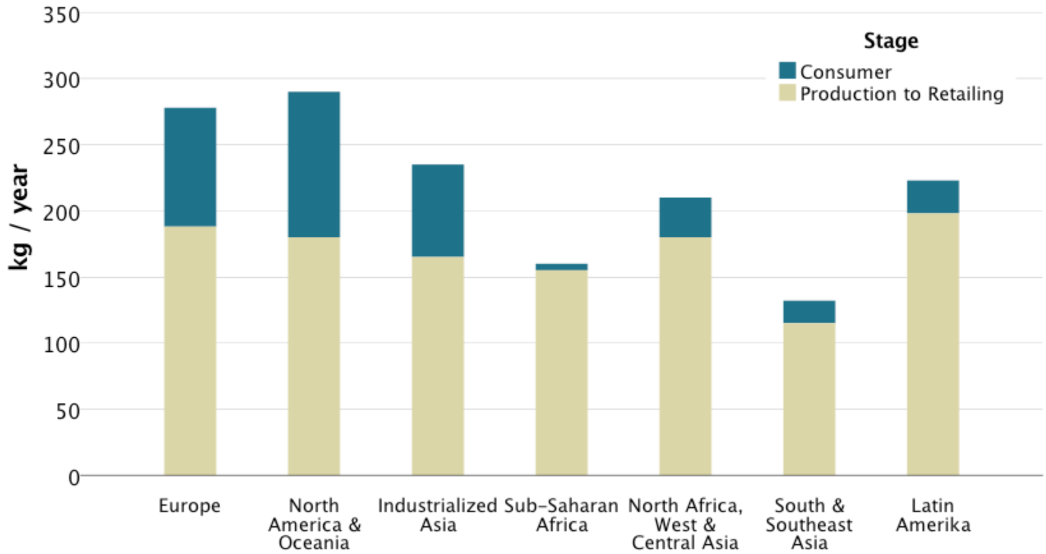

Figure 1.: Per capita food losses and waste in the world (kg/year). Source: Gustavsson, et al. (2011), page 5. The Food and Agriculture Organization of the United Nations (FAO).

between 55 and 64 years generated the greatest amounts of avoidable food waste in terms of cost. And conversely, individuals who were at retirement age wasted the least. Other research found a slight increase in the amount of food thrown away until the age of 40 and a sharp increase among those who were 60 or older (Jörissen, Priefer, and Bräutigam, 2015). However, these differences between age groups were small (Wrap, 2008). According to Wrap, a better predictor of food waste amounts is the size and the composition of households. Larger households, for example, were found to waste the most while single-occupancy households the least (Wrap, 2008); households shared by unrelated or related adults with children generated around 6.9 kg and 7.4 kg food waste per week, respectively. In contrast, single-occupancy households generated 3.2 kg food waste per week.

1.1.1 Decision-making around food

Consumers' wasteful behaviors are influenced by a large variety of factors. According to Contento (2010), factors that affect decision-making around food can be biologically determined such as taste and hunger, or can depend on experiences such as associative conditioning or mere exposure. Furthermore, food practices can be influenced by intra-personal factors (e.g., attitude, motivation, values, knowledge etc.), inter-personal factors (e.g., family and social networks) and the environment we live in. Due to time demands, food-related behaviors have become accustomed or unconscious (Cohen, 2008; Ganglbauer, Fitzpatrick, and Comber, 2013), resulting in wasteful behaviors. These wasteful behaviors could further be the result of a lack in planning, the unpredictability of daily activities, overbuying, expiry dates, simply forgetting, or a lack in knowledge (Ganglbauer et al., 2013). Wrap (2008) showed that over a third of all food is thrown away because they were perceived as 'inedible', and the next most significant reasons were meal leftovers and expiry dates. All these factors can result in detrimental effects on human health as well as on our environment. And understanding them could give us better insights in how to approach wasteful behaviors and design effective interventions.

1.1.2 Raising awareness: A key approach

One key approach to reduce environmental impacts of food-related behavior is by raising consumers' awareness. This could be a challenging task, given the accustomed nature of food-related behaviors and the variety of factors that might influence food-related decision-making. Nevertheless, the United Nations have set goals to reduce food waste by 50 percent and food supply chain resource inputs by 20 percent before the year 2020 [2]. Additionally, the United Nations Environmental Program (UNEP) have set goals for raising awareness on the value and environmental impacts of food people eat. UNEP aims at redirecting consumption patterns to less resource-intensive foods or behaviors (Moomaw et al., 2012).

1.2 CURRENT SOLUTIONS

Despite an increasing concern in ecological sustainability (i.e., such as energy and water consumption), researchers and designers have paid little attention to domestic food waste and how technology could aid. Generally, current methods to raise consumers awareness around food waste occur at schools or through public campaigns (Thönissen, 2010). These methods, however, might not be effective as information is delivered in a context that is irrelevant to the food practices at hand. In the field of Human-Computer Interaction (HCI) and Pervasive Computing, researchers have tried to apply influence strategies closer to homes. For example, they have explored the use of mobile applications and its impact on self-reflection: the use of a diary for wasted foods was found to stimulate deeper insights of daily practices (Ganglbauer, Fitzpatrick, and Güldenpfennig, 2015). Another example is a trash bin with a camera attached on the underside of the lid that automatically captured digital images. These images were then uploaded to an application on Facebook where they could be explored by all users of the system for mutual reflection (Thieme et al., 2012). Researchers have also tried

2 http://www.eu-fusions.org/

to improve visibility of in-home availability through cameras (Ganglbauer et al., 2013) or a color code scheme (Farr-Wharton, Choi, and Foth 2014) on the inside of a refrigerator. So far, these solutions merely focus on individuals or small households. We should, however, also critically think of solutions at a more collective level and consider the broader social context in analyzing pro-environmental behavior (Mozo-Reyes, Jambeck, Reeves, and Johnson, 2016).

1.3 THE PROBLEM STATEMENT AND PROPOSED SOLUTIONS

This dissertation takes a collective approach by focusing on larger households or communities. This entails the importance of studying social behavior, a critical aspect of daily life with enormous impacts on the design, use and acceptance of technology. In general, food practices are highly sociable in nature. Studies have shown that the use of social influence or media to motivate change has promising potential but is under explored (Foster and Lawson, 2013). This also entails the importance of considering influence strategies that can be supported by technology and integrated within our daily lives: our behaviors around food are accustomed and unconscious and therefore, it should catch consumer habits truly as well as keep interactions at a minimum. Current developments in domestic pervasive computing are working towards technology that could seamlessly be integrated in our daily environments to improve resource efficiency, and impact food and waste behaviors. Based on these considerations, a community-based social system is proposed and envisioned (See figure 2) comprising two innovative concepts.

This dissertation works towards:

I *a community-based social system,*

II *that tracks users food waste potential, and*

III *redirects behavior through social influence strategies and awareness towards more sustainable food-related practices.*

The main interest in this work is at understanding how to design this system (or such a system) to raise awareness and ultimately motivates and engages consumers in reducing food waste at the collective level. This is done by exploring and evaluating the two concepts independently. These concepts are introduced next.

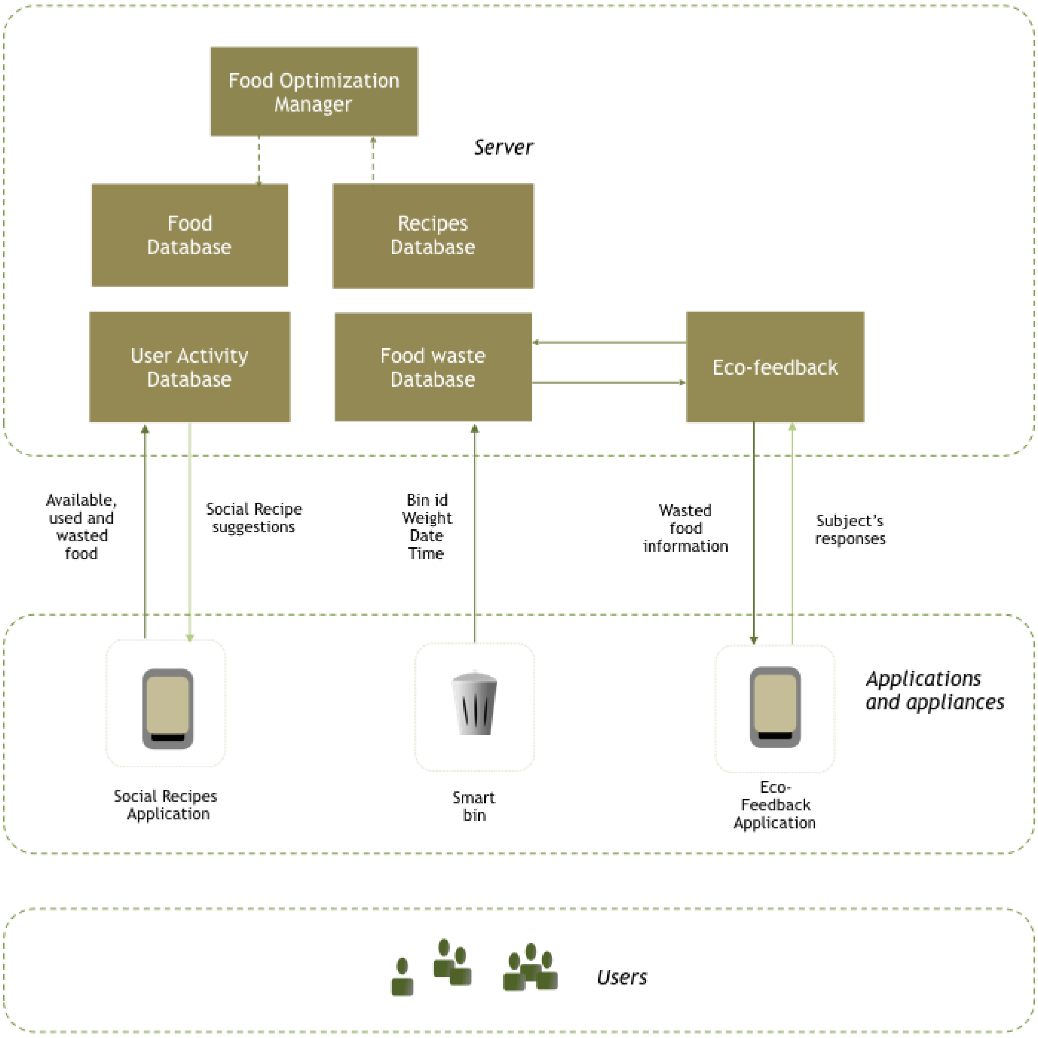

Figure 2.: A high level representation of the community-based social system. The Social Recipes application (*Concept 1*) collects available, used and wasted ingredients from users and stores it in a server. Food availability is then handled by a food optimization manager who selects and sends Social Recipe suggestions back to users through the application. The wasted ingredients are also collected by a smart bin, which data is processed by an eco-feedback manager and fed back to an eco-feedback application, E-COmate, for data visualization that is visible to all users (*Concept 2*).

1.3.1 Concept 1: E-COmate

E-COmate is based on eco-feedback, a commonly used strategy to increase awareness of resource use and to encourage conservation (Froehlich, Findlater, and

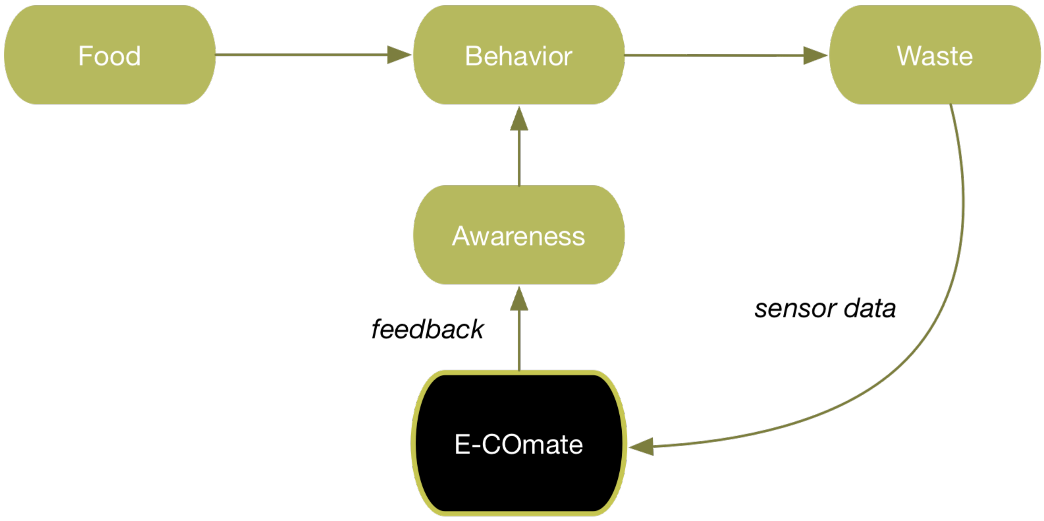

Figure 3.: The output value (i.e., food waste) helps controlling the next output value.

Landay, 2010). So far, however, little to no attention has been paid on how to apply eco-feedback on reducing household food waste with the aim to increase awareness and lower the impact of every day food-related decision-making on the environment. E-COmate measures the weight of food waste and visualizes this information directly to users in metaphorical units. It intends to redirect behavior through transparency and social comparison within the right context. The interactivity and immediacy of eco-feedback was also found to be key elements for a more effective approach, for instance, towards recycling behaviors (Mozo-Reyes et al., 2016). The principle of feedback, where an output value controls or influences the next output value, is presented in figure 3.

1.3.2 Concept 2: Social Recipes

Social Recipes aims at improving awareness of what one has available (in contrast to what one has wasted). Eco-feedback has been criticized because it does not necessarily direct behavioral change and just informs users of what one has wasted without indicating how to act. Therefore, suggestions were made that for technology to be successful in changing behaviors, it should be designed to encourage action (Maitland, Chalmers, and Siek, 2009). This was argued to have impacts on creativity, pleasure and nostalgia, gifting, connectedness and trend-seeking behaviors. With Social Recipes, the intention is to encourage the use of high-risk ingredients owned by different individuals in a creative and social alternative. Social Recipes promotes food sharing as a way to support sustainability. It uses the principle of feed forward as presented in figure 4.

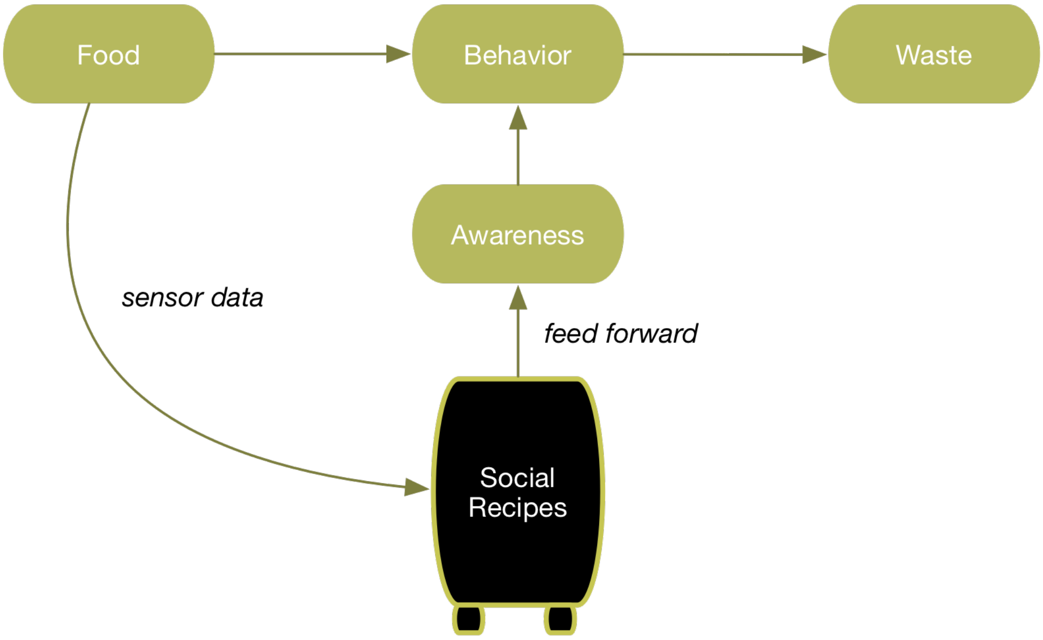

Figure 4.: The input value (i.e., food) is used to form suggestions to control the output value.

1.4 THE THESIS OVERVIEW: OBJECTIVES AND APPROACH

The process of evaluation of these concepts is divided into 3 parts. In the first part, a high level rationale is provided for the proposed solutions based on current state of the art (i.e., envisioning). In the second part, the development of technological probes are described, their deployments and evaluations in domestic environments (i.e., exploration). The last part discusses general design guidelines, contributions of the dissertation, study limitations, directions for future research, and considerations beyond this work (i.e., reflection).

1.4.1 Part 1: Envisioning

A high level rationale for the proposed solutions is provided by exploring the most common food waste types, the factors that might influence wasteful behaviors, current technological solutions, and further design opportunities. In this dissertation, the most important key element is the social context and the focus on larger households and communities. As part of this social aspect, interdependence should be emphasized. In general, this is expected to help consumers understand the impacts of a community beyond the individual. This also raises the question whether (collective) perception is linked to sustainability. A fundamental link might provide implications on *how* the environment should be designed for more effective support in raising awareness for sustainability. In this part, the following research questions are answered.

Research question 1 (in *Chapter 2*). *What is wasted most, for what reason, and hence what does this mean for the design of interventions?* To answer this question, a one-month exploratory study was conducted where participants were asked to collect grocery receipts. These were later used as cues for biweekly retrospective interviews on their food wastage. The study aimed at familiarizing with users waste and their reasons. Together with current research in how people make decisions around food and related work in Human-Computer Interaction, answers to this question provided insights in design opportunities.

Research question 2 (in *Chapter 3*). *Are those who adopt more sustainable practices have a bias towards a more global perception style?* To answer this second question, an online reaction time experiment was conducted based on the global-precedence task from Colzato et al. (2010), along with standardized questionnaires: Ecological Motives Scale (EMS) from Schulz (2001) and the General Ecological Behavior (GEB) questionnaire from Kaiser and Wilson (2004). Respondents were divided into two groups, a sustainable and a non-sustainable group, and compared for global-precedence effects. Findings could support the idea of designing the environment in such a way it directs our perception towards a more global style to motivate and support sustainable practices.

1.4.2 Part 2: Exploration

Based on the state of the art and findings from part 1, a system is proposed with 2 different elements or concepts. This part explores *how* to design this system for domestic food waste prevention through the use of technological probes. These probes were developed and deployed in homes and student residences. The data during these deployments were gathered trough a mix of quantitative and qualitative methods such as visual inspections, questionnaires, through the technological probes, a messaging application, semi-structured interviews, and a focus group. Findings were used to inform design implications. In this part, the following research questions are answered.

Research question 3 (in *Chapter 4* and *Chapter 5*). *Does feedback (i.e., concept 1: E-COmate), with or without social comparison information, impact food waste patterns, awareness or active (social) engagements? If so, how?* To answer this third question, a pilot study was conducted with a first generation prototype followed by a two-month home deployment of a second generation prototype in a student residence. In this communal 2-month deployment, a between-subjects design was adopted to explore the impacts of feedback.

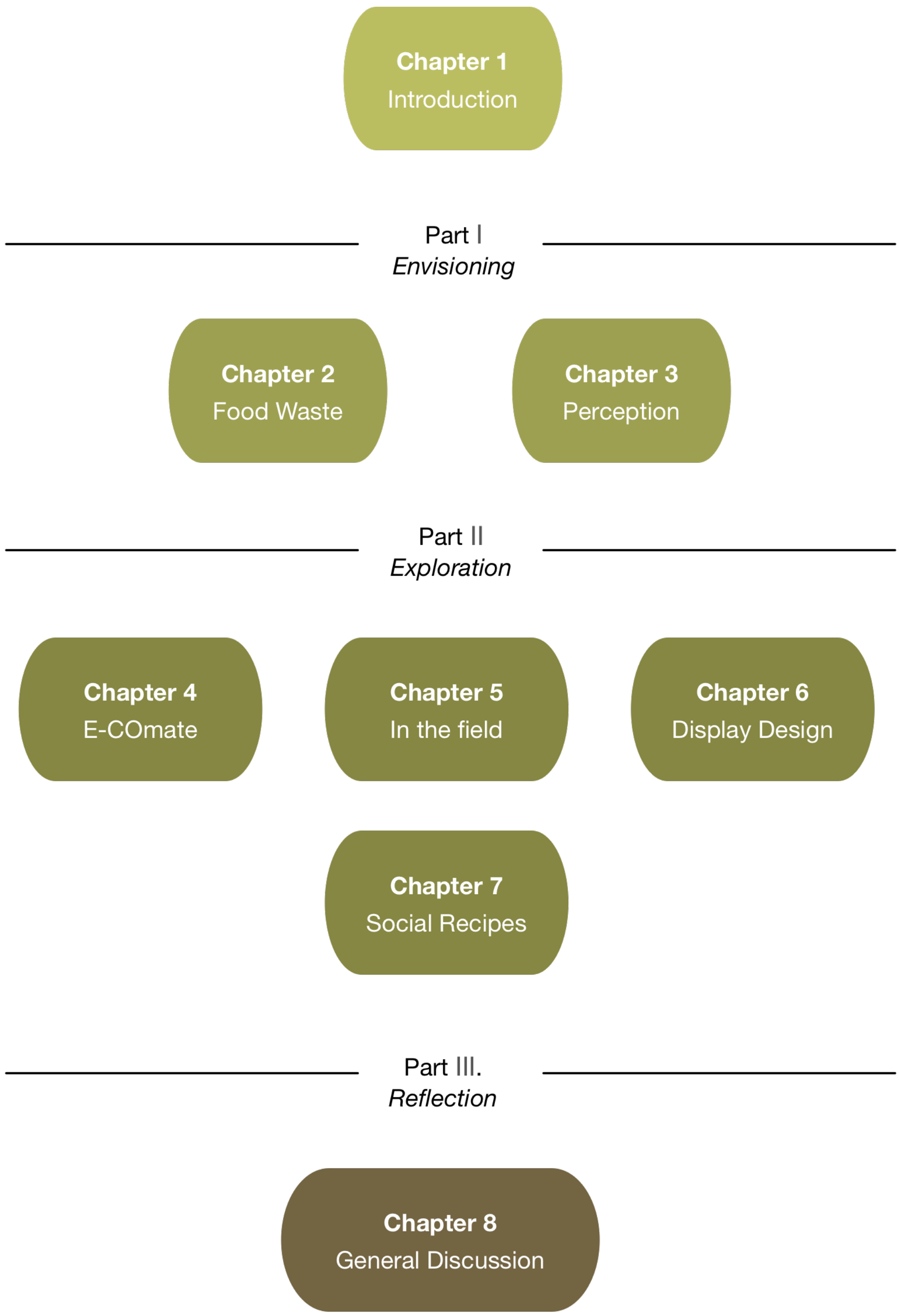

Figure 5.: An overview of the chapters discussed in this dissertation.

Research question 4 (in *Chapter 6*). *How to design display visualizations that motivates consumers in reducing food waste?* To answer this fourth question, participants from *Chapter 5* were asked to evaluate different display design visualization and comment on how they see it as (not) useful in motivating them to reduce food waste.

Research question 5 (in *Chapter 7*). *Does feed forward (i.e., Concept 2: Social Recipes) impact awareness or active (social) engagements? If so, how?* To answer this last question, a focus group was conducted to explore expectations with the Social Recipes concept. This was followed by a one-month home deployment, where the Wizard of Oz method was adopted to create an experience of the concept in a daily life setting. Here, Social Recipes was evaluated against feedback information.

1.4.3 Part 3: Reflection

In this last part of the dissertation, the key contributions of this work are discussed. This part also includes a summary of design guidelines extracted from the findings presented in *part 1* and *part 2*, and a reflection on the adopted research and design processes. In this last chapter, limitations, future work and implications beyond this work are further discussed.

Part I.

Envisioning

2 FOOD WASTE

Consumers are the largest contributors of overall waste generation. And household composition is one reliable predictor of food waste amounts: for example, larger households with unrelated adults were found to waste the most (Wrap, 2008). In this chapter, an overview is provided of *who* is wasting most and *what* is wasted most, and the factors that might influence them. This chapter further discusses previous research on how consumers make decisions around food and the factors influencing sustainable choices. This information is believed to help in better understand implications for designing interventions. Finally, related work with proposed solutions and approaches are presented, concluding with insights in design opportunities for domestic food waste prevention.

2.1 LARGE HOUSEHOLDS

Food waste occurs in all types of households. Nonetheless, there are slight differences between socio-demographic groups (Wrap, 2014); older households and those where the main earner is retired generate less waste than other generations. A better indicator of food waste amounts seem to be related to the number of occupants in a household and its composition; larger households were found to waste the most while single-occupancy households the least in terms of weight (See figure 6 for the differences in weight by household size). For example, households shared by unrelated or related adults with children generated around 6.9 kg and 7.4 kg food waste per week, respectively, while single-occupancy households generated 3.2 kg food waste per week. However, when the average is calculated per person, large households generate less waste than single-occupancy

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Lim, V., Yalvaç, F., Funk, M., Hu, J., Rauterberg, M. (2014). Can we reduce waste and waist together through EUPHORIA?. *In Proceedings of the PERCOM Workshop on Social Implications of Pervasive Computing* (pp. 382 - 387). New York, NY: IEEE.
Lim V., Yalvaç, F., Funk M., Hu J., Rauterberg M., Regazzoni C., Marcenaro L. (2014). Design implications for a community-based social recipe system. *In Proceedings of the World Congress on Sustainable Technologies* (pp. 19 - 26). New York, NY: IEEE.
Lim, V., Funk, M., Regazzoni, C., Marcenaro, L., and Rauterberg, M. (2017). Designing for action: an evaluation of Social Recipes in reducing food waste. *In International Journal for Human-Computer Studies, 100*(2017), 18 - 32.

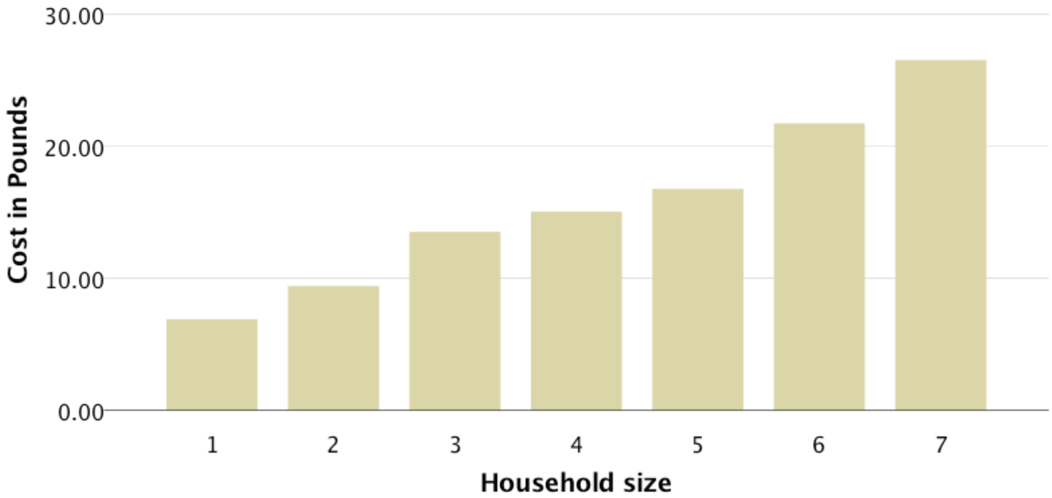

Figure 6.: Mean average cost of food waste by number occupants in a household. Source: Wrap (2008), page 172.

households (See figure 7 for the differences in costs per person by household size). Despite these lower food waste amounts calculated per person, *more* food could be saved from being wasted if interventions target large households. Large households have more opportunities for prevention because of the social setting. For example, they have easier access to share and coordinate with other individuals living in the same house in contrast to a single-occupancy household. Moreover, individuals in large households can provide mutual reflection, provide norms, exchange knowledge, and trigger meaningful interactions for sustainability purposes. In this work, unrelated adults living in large households are therefore of main interest.

2.1.1 Students and young professionals

A significant part of consumers living in larger households are students and young professionals. Recently, the United Nations estimated the global population of young people has hit 1.8 billion. This means that there are more young people in the world than ever before, making them an interesting target group. With the abundance of food and its availability anywhere and anytime, young adults have adopted different values towards food than older generations who have experienced difficult times. Moreover, in comparison to these older generations, young adults are likely to be less knowledgeable, unaware or more reluctant to sustainable food practices. This work focus on designing for this target group specifically and their specific needs. Studying a uniform group follows Wrap's (2014) suggestion to design interventions with the specific needs of

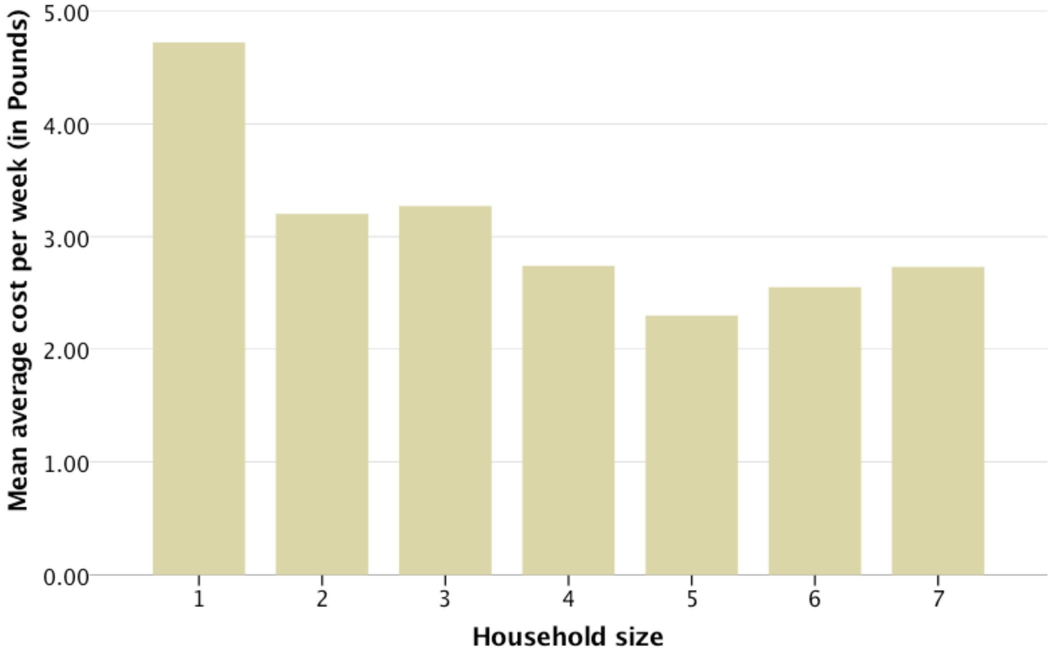

Figure 7.: Mean average avoidable waste per week per person. Source: Wrap (2008), page 172.

different groups in mind because of the complexity of waste generation. In the following section, a first exploratory study is discussed conducted to familiarize with the type of food waste and reasons within this niche of consumers.

2.2 AN EXPLORATORY STUDY ON THE TYPE AND REASONS OF WASTAGE

In this study, participants logged their food waste for a period of a month and were interviewed once per 2 weeks (i.e., with a total of 2 interviews per household). The objectives in this study were: (1) to identify the most common food waste types and reasons in this specific target group, and (2) to explore expected experiences of a community-based social recipe system. In this section, only objective 1 is discussed. For objective 2, see *Chapter 7*.

2.2.1 Methodology

Participants

The study was carried out with 8 groups of friends or neighbors with a total of 27 individuals between 22 and 31 years of age (See table 1 for participants demographics). All participants were living in urban cities in the Netherlands: 5 groups were living in the same house (B, E, F, G and H), and the remaining groups (A, C and D) were either neighbors or were very good friends of each other but not living together. They were included in the study for the evaluation of the Social Recipes concept further discussed in *Chapter 7*. The remaining groups were included to see how they find the concept motivating or demotivating: differences in spatial distance was expected to provide additional insights for the design of the Social Recipes concept. Participants were recruited through Universities' facebook pages (i.e., the International Student Network, and Industrial Design), by means of an information/invitation letter delivered in their mailbox (i.e., for those living on campus), and through personal networks. All participants were visited at home after work hours and were compensated with vouchers.

Study procedures

At the beginning of the study, all participants were provided with a small box, a black marker, a small table bin, and a kitchen scale. They were asked to collect their grocery receipts during the study period and use the box to store their receipts and the black marker to cover any item that was considered private. These receipts were later used as cues for biweekly retrospective interviews on their food wastage in the last 2 weeks: all participants were interviewed twice, individually, in couples, or in the presence of other group members. The purpose of the interviews was to get familiarized with the type of food they commonly waste and their reasons for wasting. This was done by going through the items one by one and by asking participants if they have wasted anything. If they did, they were asked to give an estimation of how much it was in percentage of the total item and why it was disposed. Participants were further instructed to use the table bin for all food-related organic waste including edible as well as inedible parts of food items such as bones, tea bags, egg shells, and fruit peels. The inclusion of inedibles was done to prevent differences in the definition of edibility. Participants were asked to weigh the table bin every time before they empty it and to write down the amount on a log sheet. Log sheets were provided and replaced after each interview.

Data analysis

To simplify the analysis, each food item was considered equal to a single fruit or vegetable such as a banana or cabbage, but also a basket of smaller fruits or

Group	N (m/f)	Profession	House type	Relation	Consumption habits
A	2 (m)	International students from China and India	Single studios on campus	Neighbors	They all mainly cook for them selves during the week and prepare their dinners for two to four days.
B	2 (m) 1 (f)	International students from Portugal and Germany	Apartment	Two are friends	The two friends always buy food and have dinners together, while the other cook for herself because of her vegetarian diet.
C	2 (m) 2 (f)	Young professionals from Turkey and Australia	Each couple in different apartments	Good friends	Each couple eat alone, except for certain occasions they get together.
D	5 (m)	International students from India	Two on campus, one in an apartment for 3, two in an apartment for 7	Good friends	Get together almost every weekend to go to the market, cook and eat.
E	3 (m)	Students	Apartment	Good friends	They do many activities together, and share similar friends.
F	2 (m)	Young professionals	House	Regular house mates	Very busy, cook and eat at home only couple of times a week.
G	3 (f)	Students	Student residence	Sorority friends	Socially very active and have dinners in big groups at least once a week.
H	5 (f)	Students	Student residence	Friends	Socially very active, members of a sports club, cook and eat together regularly.

Table 1.: Participants demographics.

Categories	Description
Ways of consumption	Includes items that were used for flavoring or parts that were cut away because of the recipe.
Items gone badly	Includes all items with visual characteristics of decay such as mould, decoloration, or growths through the skins, for example, in potatoes. These could further be caused by forgetfulness, busy lives, too big purchases, unpredictability of longevity, change of meal plans, the weather, etc.
Doubtful items	Includes visual unattractiveness such as drought or over-moisture, expiration dates, items that were left open in the kitchen for one or several days and were not trusted anymore in terms of quality, and items that were just considered old and had been in the fridge for a long time. These could also further because by forgetfulness, busy lives, social activities or knowledge.
Dealing with leftovers	Includes cooked or prepared ingredients that were left left after dinner but not worthwhile saving (e.g. too little to save or not tasting good) or leftovers without plans for being used in the near future. This category also includes meals that were saved for days with the intention of usage but were eventually forgotten (cf. causes above).
Other	Includes other reasons such as the method of saving (e.g., without foil), food items that were partly bad at the time of purchase, unexpected taste, difficulty in getting it out of a package or simply just due to a bad fridge or pan.

Table 2.: Categorisation of reasons for wasted food.

vegetables such as cherry tomatoes, or one portion of rice or pasta suitable for one meal. Each reported food item was further categorized into different food groups: fruits, grains, dairy, vegetables, meat and fish, or other (e.g., sandwich spreads). A thematic analysis was conducted to categorize the reasons that were provided for wasting.

2.2.2 Findings

Over a one-month period, a total of 231 food items were wasted excluding drinks (other than milk), desserts, cookies, and confectioneries. That is almost 9 items per person. Around half of these wasted items were vegetables, of which most were disposed partly with an average of 64 percent of the whole item. This indicates the significance of targeting vegetables. The reasons provided for wasting can be categorized in one of the following categories: way of consumption, items gone badly, doubtful items, dealing with leftovers, or other (See table 2 for description of each category). Vegetables were found to be wasted due to physical deterioration (N items = 38) or were expected not to be edible and thus doubtful in quality and safety (N items = 41). See figure 8.

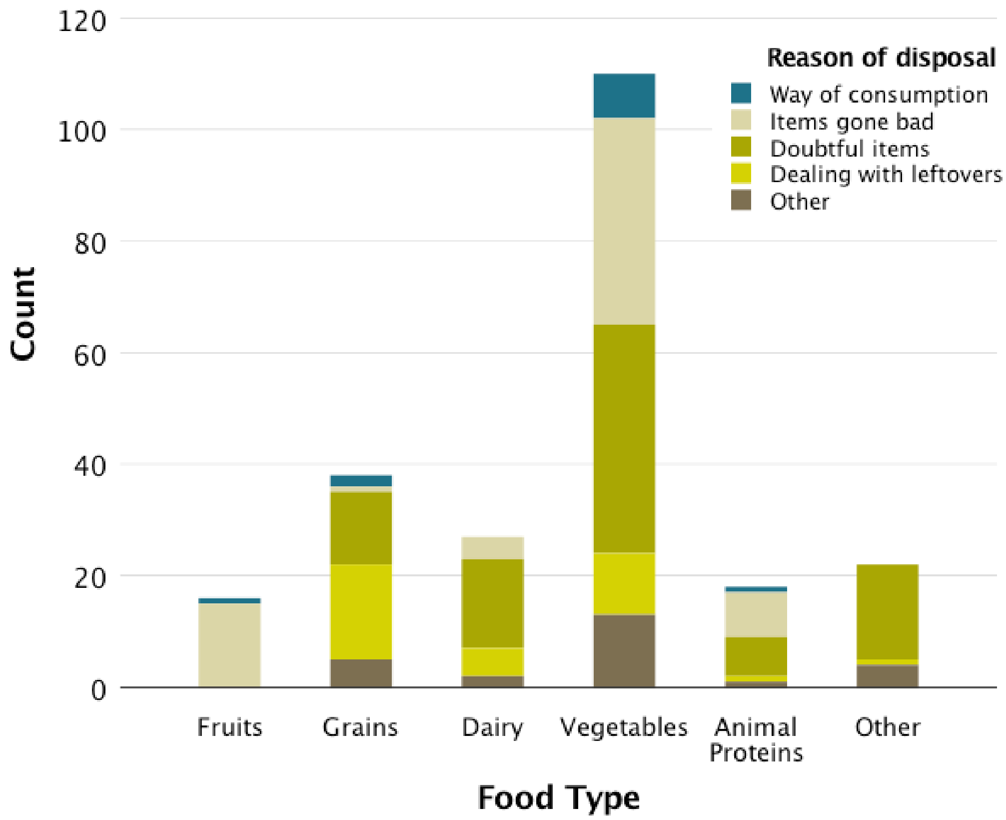

Figure 8.: Categorization of reasons for wasted food and its segmentation per food type.

2.2.3 Conclusion

These findings show the potential of targeting raw perishables (i.e., vegetables), which supports findings from Ganglbauer et al. (2015). Vegetables don't get immediately used, and hence becomes sensitive to deterioration. Design interventions should focus more on this, but the question is *how*? Many factors could influence food waste. Although the reasons provided here sounds straight forward, factors impacting food waste are complex. The next section aims at providing an overview of related work on our decision-making processes around food, sustainable practices and how this leads to food waste.

2.3 DECISION-MAKING AROUND FOOD

We make decisions about food continuously on a daily basis: when to eat, what to eat, with whom, and how much. These decisions can be very complex and influenced by many factors. Contento (2010) divides the factors that influence our food choices into 4 layers (See figure 9). The first layer contains biological predispositions such as taste and hunger which depends on our biological structure. The second layer includes sensory-affective factors such as associative, physiological, and social conditioning (e.g., familiarity and parenting practices) that we have experienced throughout our lives. The third layer includes person-related determinants such as beliefs, norms, attitudes and skills that we have developed throughout our lives. These determinants are intra-personal but can also be interpersonal (e.g., family and social networks). Finally, the fourth layer includes social and environmental determinants such as the build, cultural, economic and informational environment we currently live in (e.g., food availability, public policy, time, price and media) that are affecting our decision-making. These layers shows the complexity of our decision-making around food, influenced by a wide-range of factors.

2.3.1 Factors influencing sustainable choices

Whether we adopt sustainable choices around food depends on a variety of factors that could be explained within Contento's framework. In general, we commonly agree that adopting a sustainable lifestyle could reduce impacts on our environment. A sustainable lifestyle includes successful attempts to reduce the use of natural and personal resources, but requires active effort such as in altering methods of transportation, selection of ecologically responsible food, as well as waste prevention. However, despite active engagements, it is not always reflected in everyday practice (Vermeir and Verbeke, 2008). A number of factors influence the likelihood that we act sustainably. For example, gender is found to be a biological determinant for adopting sustainable practices. Females score

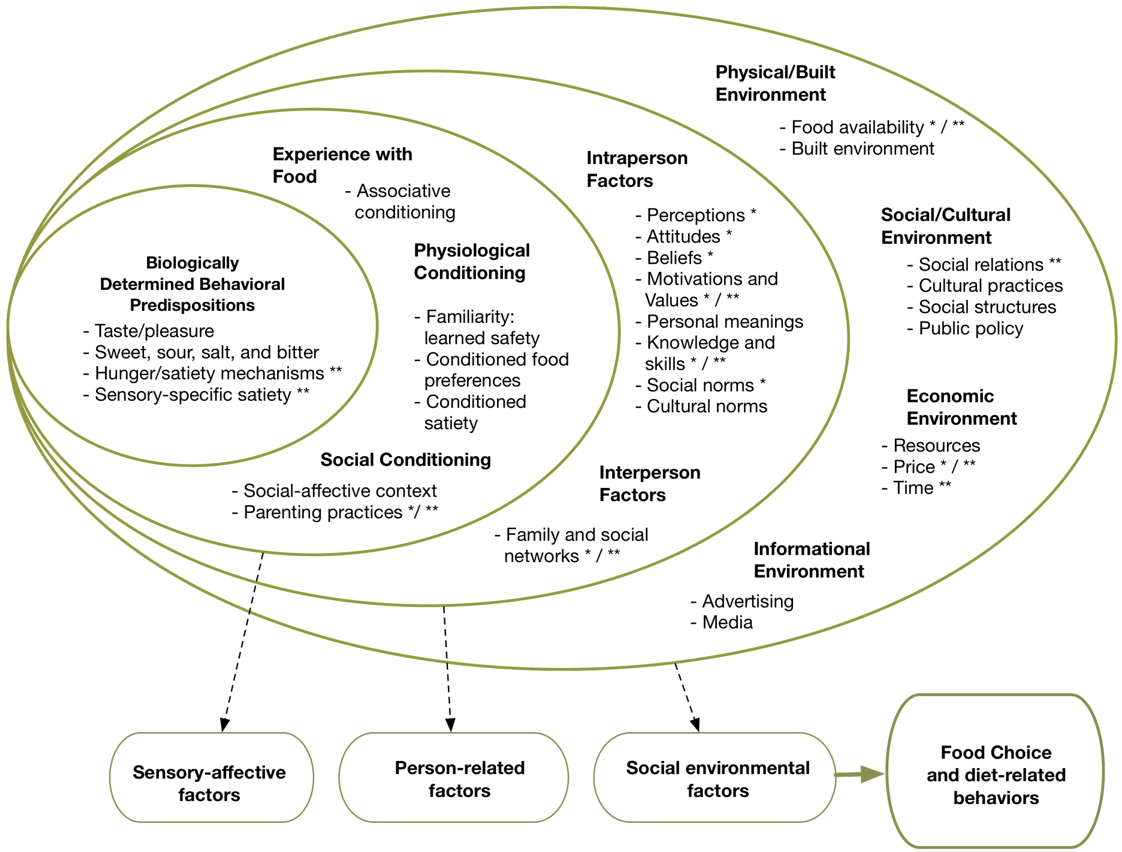

Figure 9.: Factors influencing food choices and dietary behaviors. Source: Contento (2010), page 37. Note: factors with "*" indicate determinants of sustainable behaviors derived from other sources discussed in the text. Factors with "**" indicate determinants of food waste behavior, also derived from other sources discussed in the text.

higher in agreeableness and openness, which are traits associated with sustainable behaviors (Luchs and Mooradian, 2012; Brunner et al., 2007 as described in Ganglbauer 2013). Social conditioning through parenting practices and our family and social networks are also important determinants. For example, we are more likely to adopt sustainable behaviors if our families share positive attitudes towards sustainability (Ganglbauer et al., 2013), which further depends on our families' social class (Laidley, 2013). Other important factors are intra-personal such as perceived food availability, perceived consumer effectiveness (Vermeir and Verbeke, 2006), knowledge, our education level together with general beliefs, and being concerned about the environment (Milfont, Duckett and Cameron, 2006; Olofsson and Ohman, 2006; Mobley, Vagias and DeWard, 2010; Brunner et al., 2007, as described in Ganglbauer et al., 2013). Furthermore, social environmental factors that affects our decision-making are food availability and the price of food (Brunner et al., 2007, as described in Ganglbauer, 2013). Previous research have also considered evolutionary bases for why people sometimes act in destructive and ecologically damaging ways. Griskevicius, Cantu, and Vugt (2010) proposed that a large portion of human-inflicted ecological damage is caused or exacerbated by five ancestral tendencies which have devastating consequences in the modern world; propensity for self-interest, motivation for relative status, proclivity to unconsciously copy others, predisposition to be shortsighted and proneness to disregard impalpable concerns.

Factors influencing food waste

One example of a sustainable practice is when we successfully attempt to prevent or reduce food waste. Several factors have been associated with food waste behaviors specifically. Starting from our biological inclination, every time we smell food, dopamine is released to increase appetite (Abizaid et al., 2006). Hence, when we see other people eat in social settings or we pass by food stands, we sometimes have difficulty to resist compliance. This might be influenced by the activity of mirror neurons: when we observe someone who is eating a type of food we usually like, mirror neurons fire as if we perform the action ourselves (Cohen, 2008), which results in a higher probability of actually performing the action. Another biological mechanism that could lead to waste is satiety. Hunger could lead to overbuying or leftovers that might end up in the bin (i.e., caused by inaccurate perceptions of how much you want to eat in relation to what you can eat). Although these factors are difficult to control for, being knowledgeable of these factors could lower food waste amounts. For example, you could do groceries when you do not feel hungry. Other types of knowledge and skill (i.e., both intra-personal factors) that has an impact on how much we waste are awareness of the amounts of food waste[1], understanding sell-by dates, knowing when to use the fridge to store ingredients, planning meals and making lists (Wrap, 2014). Knowledge on how much people spend (e.g., economic reasons) were

1 https://wastelesssavemore.sainsburys.co.uk/projects/winnow-app

found to trigger attempts to reduce food waste and daily expenses (Ganglbauer et al. 2013). Moreover, the social environment is associated with food waste behaviors. For example, parenting practices has impact on food waste: growing up in a family with a lifestyle towards sustainability makes people appreciate the food that is available (Ganglbauer et al. 2013): people are affected by the norm that exists in their group. However, the social environment has also been associated with more waste: e.g., unpredictability of daily (social) activities and social relations increases food waste. Caused by the increasing demands of our time for (social) activities, everyday behaviors around food have become habitual and unconscious. The lack of time and the abundance of activities could further result in forgetting (Cohen, 2008; Ganglbauer et al., 2013): findings have shown that people with less time available for food-related activities generate the most waste (Wrap, 2014)..

In sum, consumers are mostly unaware (e.g., lack of knowledge of the amount they waste and the value of the waste), are influenced by their social environment (e.g., the group norm), and make choices that are unconscious or habitual in nature. Based on the factors discussed above, strategies to tackle wasteful behavior should improve perception (i.e., awareness) or knowledge without requiring much time and cognitive effort from consumers. Accordingly, Griskevicius et al. (2010) suggested for influence strategies to be optimally effective, they must work with, rather than against, evolved tendencies. Also according to Manning (2009), one way to empower sustainability is to make sustainable actions appealing to the unconscious and impulse associative system so that a sustainable action is appealing and grabbing for rational reasons as well as gut-feeling. This should be done with consideration of the social environment.

2.4 CURRENT SOLUTIONS

2.4.1 Increasing awareness at a global scale

So far, the most common approach aims at raising awareness in schools or public campaigns (Thönissen, 2010). Consumers get informed about topics such as food purchasing, storage, preparation, or actual shelf life. However, the information is delivered in a context that is irrelevant for the targeted food practices at hand. Consumers might gain knowledge and have good intentions, but this might not be reflected in their daily lives: the frequency of past behaviors or habits might interfere (de Vries, Aarts, and Midden, 2011). One way to successfully support sustainable actions, is to engage consumers in their direct environments relevant for the targeted food practices. Consumer could be supported with situational cues that repetitively help them take actions towards goal fulfillment. This might then lead to a certain degree of automatic behaviors where old habits are broken and new ones are created (de Vries et al., 2011). This requires approaches at a more local scale. Therefore, we should improve our understanding in *how* interventions could effectively support sustainable actions in domestic environments and how to make these actions more appealing. The relevance of addressing the issue of food waste locally, and hence with a bottom-up approach, was one of the main outcomes in the first Global Food Security conference held in 2013.

2.4.2 Increasing awareness at a local scale

Researchers in the field of Pervasive and Persuasive Computing and Human Computer Interaction (HCI) have taken influence strategies to raise awareness closer to homes. With consideration of how we make decisions around food and how this leads to food waste, it is crucial to integrate technology (i.e., that intends to help raise awareness) with daily activities, so it can catch current habits truly as well as keep interventions with users at a minimum. Some technological examples in sustainability research that aims at doing this are presented in figure 10, but applied to water, energy and fuel consumption. These examples use eco-feedback, a common influence strategy to increase awareness of resource use and to encourage conservation (Froehlich et al., 2010). Eco-feedback aims at increasing awareness by automatically sensing peoples activities and feeding related information back through computerized means, to foster positive attitudes towards sustainability (Pierce, Odom, and Blevis, 2008) and hence the adoption of sustainable behaviors. It replaces hidden environmental information and behavior patterns with more accessible and understandable information without requiring too much effort from consumers (Holmes, 2007). Despite the increasing concern in ecological sustainability, to date, food waste has received little attention in sustainability research. Instead, researchers has mainly put efforts in other areas such as energy and water consumption, green transportation or are not tied to any specific topic (Brynjarsdottir et al., 2012). Considering the complex but habitual and invisible nature of food-related practices, capturing and influencing food waste-related behaviors is challenging. Although, most pervasive or persuasive sustainability research focus on other topics, developments applied to food waste behavior are getting increasingly important. The latest developments in domestic environments can be categorized in: (1) sensor based systems (RFID tagging or camera tracking), which are used to track the type and amount of food and waste, and (2) mobile applications to log and track food related activities. Next, some examples are presented where these developments were used or explored to create visibility of food availability for prevention and to create visibility of wasteful behaviors for reflection.

Creating visibility of food availability for prevention

In the field of smart home environments, food sensing technology is expected to have great impacts on food waste prevention. Smart refrigerators can record ex-

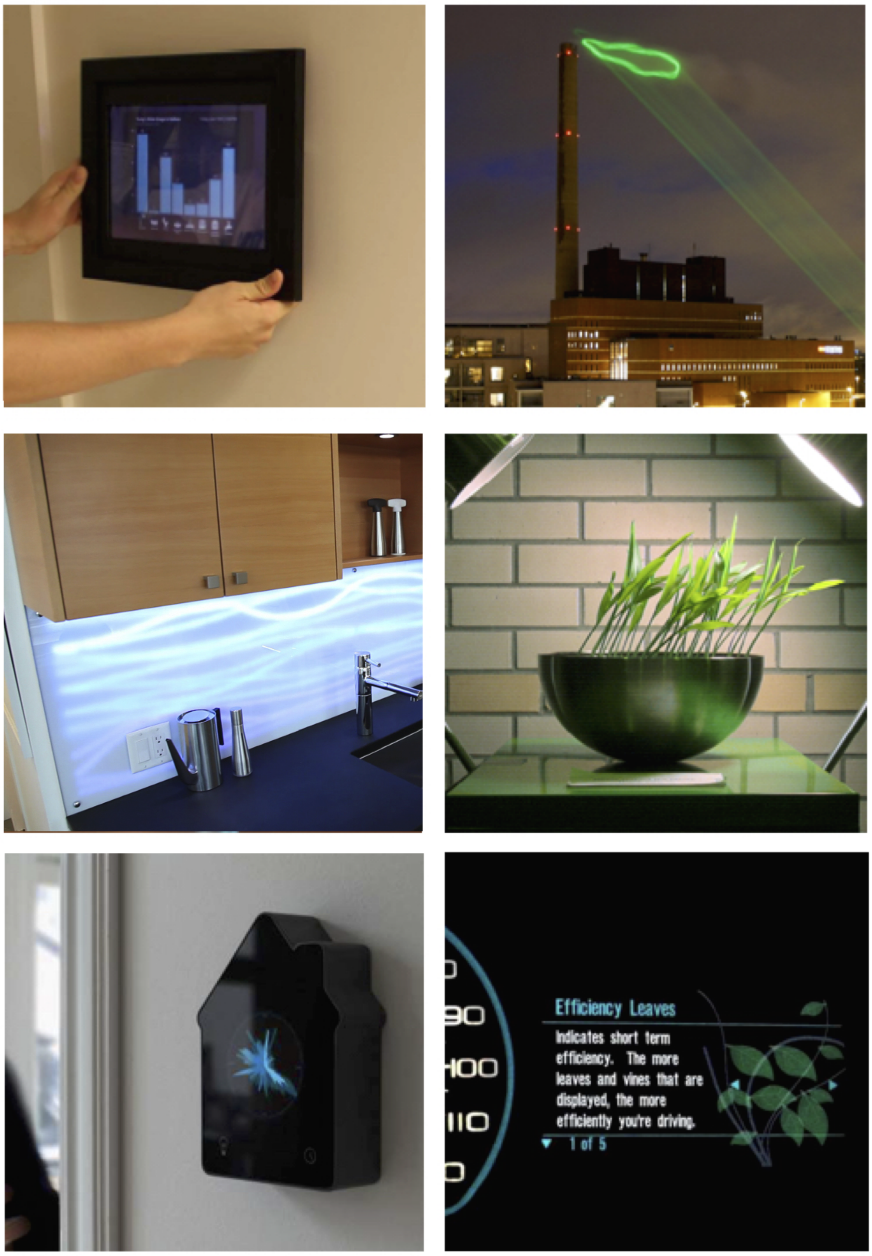

Figure 10.: Eco-feedback examples. Top left; for fixture-level water usage (Froehlich et al., 2012). Top right; for electricity consumption of a city (Nuage Vert, 2008 as described in Pierce et al., 2008). Middle left; for electricity use[a] (Rodgers and Bartram, 2010). Middle right; for recycling and waste disposal (Holstius et al., 2004). Bottom left; a clock for energy usage (Erhnberger, Broms and Katzeff, 2013). Bottom right; a smart gauge for fuel efficiency.[b]

a http://westhouse.sfu.ca/
b http://smartdesignworldwide.com/work/ford-smart-gauge/

Figure 11.: From left to right: the FridgeCam (Ganglbauer et al., 2013) and the BinCam (Thieme et al., 2012).

piration dates using bar code readers and Radio Frequency Identification (RFID) technology (Rouillard, 2012), so that food that is sensitive to spoiling can be closely monitored. The refrigerator may then alert when the food reaches a point where it must get used. RFID is a technology that connects the objects over-the-air so that the objects can be tracked and the data about them can be shared by individuals and organizations. Future research on smart refrigerators aim at an optimization of food identification with image and speech recognition techniques to improve the interaction process as well as to provide recipes based on recorded ingredients (Rouillard, 2012; Xie et al., 2013). These pervasive sensor-based approaches, including interactive fridges (Bucci et al. 2010), and fully equipped smart kitchens (Olivier et al. 2009) open up new possibilities to support food practices and reduce waste. Furthermore, RFID is used to track the food in the supply chain to guarantee the quality of products more effectively (Guillory and Standhardt, 2012 as described in Realini and Marcos, 2014). This food quality identification is expected to improve in reducing food waste in the cold supply. One recent example, that is currently in development, is an improved preservation technique that uses plastic circuits to understand actual food quality of packaged items. This could replace the currently misunderstood expiration date[2]. Another form of pervasive computing that can support consumers in reducing food waste is mobile technology. In previous work, smart phones and cameras has been attached to a fridge to improve the visibility of in-home food availability (Ganglbauer et al., 2013). Furthermore, Farr-wharton et al. (2013; 2014) introduced a mobile application that can track the ingredients inside a color-coded refrigerator with the help of pictures and food identification. Their main goal was to alert users before the expiration date to achieve a reduction in food waste.

Creating visibility of wasteful behaviors for reflection

Mobile technology has also been used to create visibility or awareness of wasteful behaviors. Ganglbauer, Fitzpatrick, and Molzer (2012) presented a mobile food waste diary allowing consumers to reflect on how much food they actually waste. Their diary addresses visibility in different phases of food practices for self reflection and was found to stimulate deeper insights about the relationships between food waste, experiences, habits, knowledge, occurrences and intentions to change (Ganglbauer et al., 2015). The reasons of food waste were made available to other users in order to encourage sharing and mutual reflection. Another recent example for reflection is BinCam, a system that replaces an existing kitchen bin. The bin has an attached camera on the underside of the bin lid to automatically capture digital images. These images are then uploaded to an application on Facebook where they can be explored by all users of the system for mutual reflection. With this system, researchers aimed at motivating reflection

2 http://www.electronicsnews.com.au/news/plastic-analog-to-digital-converter-tests-food-fre

and behavioral change in food waste as well as recycling habits of young adults (Thieme et al., 2012). BinCam and the food waste diary aimed at encouraging sharing of waste behaviors and mutual reflection. BinCam, for example, enabled users to form connections with relevant others while leveraging on individual's self-interest to be socially accepted. In both systems, social networks were used to motivate sustainable behaviors. In general, social influence strategies has been found to have high potential in generating positive behavior changes (Foster and Lawson, 2013). However, research paid little attention to the use of these strategies (i.e., social influence and feedback) in reducing or preventing food waste. Finally, other examples that successfully increased awareness involved interactive appliances for cooking practices with eco-feedback of resource use (Clear et al., 2010; Kirman et al. 2010).

2.5 DESIGN OPPORTUNITIES

Current developments in pervasive and mobile technology shows new opportunities on how consumers can be supported in reducing domestic food waste in their immediate environments. Considering human decisions-making processes around food, the following opportunities are foreseen:

- **Smart technology.** With the future of of Internet in mind, the "Internet of Things" (IoT) could help in improving awareness of domestic food waste and provide solutions that are embedded in our daily lives and that require minimum time and cognitive effort from consumers. It has becoming easier for electronic means to provide frequent feedback or trigger interactions to support our decisions (Midden et al., 2008). The solutions to tackle wasteful behaviors that are discussed above, are examples of the vision of IoT, a term invented by Kevin Ashton when he introduced the idea of using RFID in the supply chain. The IoT is used to describe a system where the Internet is connected to the physical world via ubiquitous sensors. It aims at empowering computers with their own means to gather information, so that they can see, hear and smell the world for themselves without human intervention (Ashton, 2009). The IoT implies a symbiotic interaction among the real/physical, the digital/virtual worlds: things become context aware and they can sense, communicate, interact, exchange data, information and knowledge (Vermesan et al., 2009). For example, applied to the issue on food waste, a smart fridge could correct the perception of sell-by dates, provide tips for in-home available ingredients, or help in planning meals and shopping based on available ingredients. Fridges could also communicate with a smart phone when the user is nearby a grocery store to help in making purchase decisions. Furthermore, a smart bin could analyze its content and provide consumers with tips to prevent their most common wasted foods. It could also provide the consumer with other meaningful information about what is being thrown away (e.g., in metaphorical units or to raise awareness) without their initiation and always readily available.

- **Social context.** Second, food practices heavily depend on social factors. And studies showed that social media can be successful in changing behaviors (Foster and Lawson, 2013). In analyzing community pro-environmental behavior, a broader social context is required beyond the individual (Mozo-Reyes et al., 2016). As described by Mozo-Reyes et al. this social context can be subdivided into different levels to which individual behavior is generally influenced: micro, mezzo, and macro systems. The micro system includes very small family units or individuals, the mezzo system includes community groups of several individuals collected by some common ground, and the macro system includes a society or a large scale population, organization or cultures. Thence, the population (macro structure) is composed of people with a mutual goal (mezzo context), who perform established activities (micro tasks). In this dissertation, it is believed that effective interventions and social influence may be *most* effective at the mezzo level. Large scale approaches used in general conservation initiatives at macro levels where one is compared to a large group is expected to be less efficient as it would target anonymous individuals with probably different goals. Therefore, food-related technology for sustainability should aim at supporting groups of consumers (e.g., in activities such as sharing), at the mezzo level. With current developments in technology and the IoT, groups of consumers could be seamlessly connected and targeted at any moment and in any place. For example, smart fridges from different households could be connected so that users can share their content or suggest each other recipes. A smart fridge could also suggest social dinners where ingredients from different fridges are combined. And a smart bin, could provide group feedback and social comparison information so that consumers have better insights in their individual as well as collective impact. The development of technology that supports visibility of in-home ingredients or awareness of wasted foods on a collective scale could further facilitate communication and coordination between individuals or households that could help in reducing food waste.

The social context is an important aspect for the proposed system and concepts that were introduced in *Chapter 1*. Studies have shown the importance of social, as well as related personality and cognitive variables in motivating conservation (McCalley, Midden, and Haagdorens, 2005). As part of this social and cognitive relevance, we should pay attention to how we perceive the world around us: how we are interconnected with others, what we value, and how we can extend our perception beyond our own personal environments. If sustainability depends on a global perception style, sustainable food-related technology should be designed in a way that it emphasizes interdependency and transparency to support global perception and collective awareness. The next chapter intents at providing a theoretical insight on the link between global perception and sustainable practices.

3 PERCEPTION

One approach to reduce food waste that is expected to have potential is by focusing on the collective, the community. Technology could help by emphasizing interdependency and transparency within communities to raise awareness and support social interactions that could further lead to a reduction of food waste. This could call for a global or holistic perception style. In this chapter, findings from an experimental study is discussed on the relationship between perception style, pro-environmental motives and the adoption of sustainable behaviors. This relationship would provide a theoretical foundation to design technology for sustainability in such a way it supports interdependency and global perception, which are relevant aspects of both concepts introduced in *Chapter 1*.

3.1 CULTURE

Previous research on perception style has mainly studied differences between the Western and the Eastern culture. Americans, for example, were found to focus more on salient foreground objects, whereas Asians were more inclined to focus on contexts (Miyamoto, Nisbett and Masuda, 2006). These cultural differences were also observed in the change-blindness paradigm: Americans tend to be more sensitive to changes in focal objects than to changes in the periphery, while East Asians were more sensitive to context changes (Masuda and Nisbett, 2006; Boduroglu, Shah and Nisbett, 2009). Furthermore, art and photography reflects the differences in perception styles: traditional East Asian art has predominantly context-inclusive styles, whereas Western art has predominantly object-focused styles (Masuda et al., 2008). East Asians not only attend more to the field, but they also attend to it earlier and remember more about it. Recent research has explored reasons for these differences. One could be that participating in different social practices might lead to both chronic as well as temporary shifts in perception: Western cultures often stress the individual and their goals and needs, whereas Eastern Asian cultures stress the importance of the group (Nisbett and Miyamoto, 2005). This priming of independence could lead to analytic cognition,

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whereas the priming of interdependence could lead to holistic cognition (Varnum et al., 2009). Another hypothesis suggests that cognitive tendencies varies between social class: a lower class was found to be associated with more holistic cognition and more interdependent self-views (Grossman and Varnum, 2011). Further evidence showed that following rules when practicing a religion systematically changes the way people attend to visual stimuli. In a study by Colzato et al. (2010), faster reaction times for local information was found in Calvinism, which is a religion emphasizing individual responsibility. Whereas faster reaction times were found for global information in Catholicism and Judaism, religions emphasizing social solidarity (Colzato, van den Wildenberg and Hommel, 2008). Buddhists also showed increased interference from global distractors when processing local information. This was expected as Buddhists stress compassion for the physical and social environment (Colzato et al., 2010). Moreover, religion was found to affect action control in decision-making (Hommel et al., 2011).

Sustainability (as part of a culture) may also be linked to a perception style. Sustainable practices may be caused or affect basic perceptual processes in a way that those who adopt a sustainable lifestyle see from a different perspective from those who are not sustainable. More specifically, those who are more sustainable might have a more global perception style. Griskevicius et al. (2012) argued that certain mechanisms that prevents the adoption of sustainable behaviors in current society, are linked to our perception: for example, valuing the presence (e.g., we get what we want now instead of what is best in long term), disregarding impalpable concerns (e.g., such as problems that we cannot see or feel immediately) and prioritizing self-interest over group welfare could incline the absence of holistic cognition. Those who are more willing to act pro-social have an inclination for pro-environmental engagement (Kaiser and Byrka, 2011). Research so far, however, has not yet studied the fundamental link between perception and sustainable behaviors or vice versa.

3.1.1 The global-precedence effect

One commonly used measure of perception is the global-local task, which originates from Navon (1977). A global-local task can indicate how fast someone can process global and local characteristics of hierarchically constructed visual stimuli (e.g., larger letters or figures made of smaller letters or figures). This task gives rise to the "global-precedence" effect, which means that global features can be processed faster than local features. Whether one is attending more to global or more to local aspects of stimulus events is assumed to be a stable preference that depends on culture and is controlled by parameters of our cognitive system (Logan, 1996). A sustainable lifestyle, which is part of a culture, requires active effort, calling for executive-control functions in such a way that information processing and decision-making is adapted to the current task. In this chapter, it is expected that respondents who adopt more sustainable practices in daily lives to have a bias towards a more global control parameter, showing a greater global-precedence effect in a global-local task. A greater global-precedence effect indicates holistic cognition which, according to Varnum et al. (2009), requires field dependency, a broad focus on the relationship of elements, and the categorization of objects on overall similarity. Those who adopt sustainable practices might be biased towards a holistic cognition: the more one perceives its impact beyond immediate perception (e.g., global impact), the more one understands the impact of a purchase, consumption or wastage, and hence the more likely one acts on it. On the other end, analytic cognition (i.e., individuals or groups with a bias towards a more local control parameter) requires attention that is field independent, narrow focused on salient objects, and the categorization of objects on a shared property (Varnum et al. 2009). Which perceptual processing style we adopt, either holistic or analytic, is found to depend on our cultural experience. This can be examined by performing tasks that draw attention to either interdependence or independence such as the global-local task.

3.2 PERCEPTION AND SUSTAINABILITY

Overall, findings showed that different culturally characteristic environments may require different perception styles. Environments emphasizing social relations, responsibility and interdependence calls for behavior based on a global attentional focus, whereas an environment emphasizing the individual or independence calls for behavior that are based on a local focus. Interventions could, for example, direct perception to a more global attentional focus or be adapted to a persons' perception style. This leads to the following research question: Are those who adopt more sustainable practices have a bias towards a more global perception style? The main hypothesis in this study is that participating in sustainable practices might also be linked to long-lasting differences in perceptual processes, such as towards a more global attentional focus. If this hypothesis is confirmed, it could inform how to design the environment more effectively in supporting awareness.

3.2.1 Methodology

Participants

A total of 86 young adults were recruited to perform a computer-based online reaction time experiment, which takes around 30 minutes to finish. The average age was 27 with a range between 18 and 50. The nationality was mixed, but all participants used to live or were still living in Western countries. Although, most participants were atheists or did not share their religion, 23 participants reported

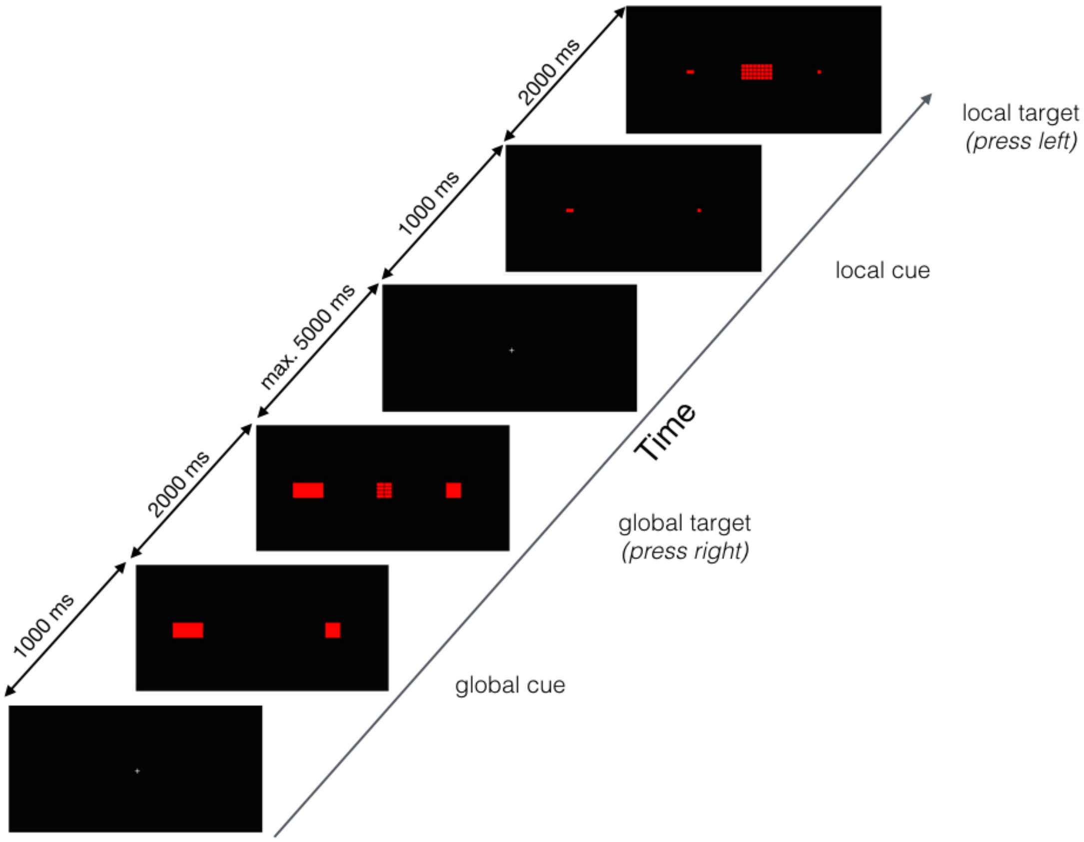

Figure 12.: The sequence of stimulus events for global and local targets. The stimuli is similar as in Colzato's et al. (2010), but adapted for the number of conditions and time of stimuli presentations.

practicing a religion (i.e., 6 were Catholic, 5 were Christian, 3 were Hindu and 9 were Muslim). Consents were provided online after the introduction to the experiment.

Data collection

The reaction time experiment was conducted online based on the global-precedence task from Colzato et al. (2010), along with standardized questionnaires: Ecological Motives Scale (EMS) from Schulz (2001), the General Ecological Behavior (GEB) questionnaire from Kaiser and Wilson (2004), and the Social Value Orientation (SVO) measure from (Murphy, Ackermann, and Handgraaf, 2011). Demographics information was collected for age, gender, religion, and country of residence. Gender, religion, and social value orientation were collected to rule out global-precedence effects related to gender, religious or social value differences, respectively.

The Global-Local task. The stimuli for the global-precedence task consisted of large (global) squares consisting of 8 smaller (local) rectangles and large rectangles consisting of 32 smaller squares. Global squares and rectangles were 93 x 93 pixels and 93 x 189 pixels respectively. Local squares and rectangles were 21 x 21 pixels and 8 x 46 pixels respectively. The space between the local figures of a stimulus was 3 pixels. Responses were made by pressing the "W" of the QWERTY or QWERTZ computer keyboard or the "Z" of the QZERTY or AZERTY keyboard with the left hand and the "P" with the right hand.

Ecological Motives Scale. The EMS measures the level in which people are concerned about the environment. It is a 12-item scale that measures three categories of concern about environmental problems caused by human behaviors. The consequences or motives could be related to egoistic (me, my future, my lifestyle and my health), altruistic (all people, children, my children and people in my country) or biospheric items (plants, animals, marine life and birds).

General Ecological Behavior questionnaire. The GEB questionnaire was administered, a questionnaire with 50 items addressing a range of behaviors including energy conservation, mobility and transportation, waste avoidance, consumerism, recycling and vicarious social behaviors towards conservation. 3 items were added to the questionnaire related to food waste avoidance: "I tend to overbuy food that gets wasted", "Past food date is a common reason for throwing out food", and "Forgetting leftovers is a common reason for throwing out food". 3 more items were added related to consumerism: "I am a vegetarian", "Sometimes I do not mind eating vegetarian", and "I want to reduce my meat consumption" (See Appendix A).

Social Value Orientation measure. The SVO measure is a person's preference about how to allocate resources between the self and another person. The measure has six primary items, used to group people who seek to maximize their gains into being pro-self or competitive and people who are also concerned with other's gains and losses into being pro-social or altruistic. All of the items have the same general form, each is a resource allocation choice over a well defined continuum of joint payoffs (See Appendix B).

Study procedures

In the global-precedence task, in each trial, a cue was presented to indicate to which dimension (global or local) participants were asked to respond to. Cues indicating the global (or local) dimension consisted of a big (or small) rectangle, presented on the left side of the target stimulus, and a big (or small) square, presented on the right side of the target stimulus. Depending on this cue, participants responded to the left ("W" or "Z", depending on the type of keyboard) or the right response key ("P"). For example, if the cue shows a big rectangle on the left of the target and a big square on the right of the target, the participant has to identify the global feature of the target. If the target is a big square consisting of smaller rectangles, the participant should press the right response key. If the target is a big rectangle consisting of small squares, the participant should press the left response key. Participants were instructed to respond as fast and accurate as possible. Faster reaction times to global targets indicate a bias towards a more global perception style, whereas faster reaction times to local targets indicate a bias towards a more local perception style. All participants went through three training blocks and one experimental block. In the first 2 training blocks (each with 20 trials), the instruction was constant across all trials (global or local); in one block participants responded to the global feature while in the other block to the local feature. In the third training block (20 trials), instruction was alternated between the global and the local task. Squares and rectangles were randomly presented. The instructions in the experimental block (80 trials) were also alternated but in predictable sequences of four "global" or four "local" trials. Both cues and targets were colored red on a black background and remained on the screen until either a response was given or 5000 milliseconds had passed. The stimulus appeared 2000 milliseconds after the appearance of the cue. The time interval between responses and the next presentation of the cue is 1000 milliseconds (See figure 12 for the stimulus events sequence). For the EMS, participants were asked to rate the 12 items from 1 (not important) to 7 (supreme importance) in response to completing the sentence: "I am concerned about environmental problems because of the consequences for ..". High scores represent higher concern within a sub-scale. For the GEB questionnaire, participants were asked to indicate whether or not they have ever engaged in a particular behavior. For each SVO item, participants were asked to indicate the resource allocation they prefer most. Data was saved as soon participants reached the last page with the request for demographic information. The total experiment took around 20 to 30 minutes.

Data analysis

First, a Hierarchical Cluster Analysis (HCA) was performed using a within group linkage method with a fixed number of clusters (i.e., two). To explore possible clusters, gender, religion, and the average scores of the sub-scales from the EMS and GEB were used as input variables. The cluster analysis was run on 86 cases, each responding to the input variables. A one-way ANOVA was then conducted to determine on which classifying variables the two clusters were significantly different. This was done for gender, religion, the EMS subscales (i.e., egoistic motives, altruistic motives, biospheric motives) and the overall score for GEB. Next, an analysis of variance was performed to test global-precedence differences between the derived clusters. Mean reaction times were analyzed using target

	Cluster	*N*	Mean	Std. Deviation	Std. Error	Min.	Max.
Gender	1	59	1.47	.504	.066	1	2
	2	27	1.48	.509	.098	1	2
	Total	86	1.48	.502	.054	1	2
Religion	1	59	1.19	.393	.051	1	2
	2	27	1.44	.506	.097	1	2
	Total	86	1.27	.445	.058	1	2
Egoistic Motives	1	59	4.275	1.8287	.2381	1	7
	2	27	5.870	.8726	.1679	3.3	7
	Total	86	4.776	1.7519	.1889	1	7
Altruistic Motives	1	59	5.017	1.5114	.1968	1.8	7
	2	27	5.750	.9482	.1825	3	7
	Total	86	5.247	1.3967	.1506	1.8	7
Biospheric Motives	1	59	5.381	1.5017	.1955	1	7
	2	27	4.731	1.3515	.2601	2	7
	Total	86	5.177	1.4797	.1596	1	7
General Ecological Behavior	1	59	33.90	4.452	.580	21	44
	2	27	26.26	4.629	.891	13	32
	Total	86	31.50	5.727	.618	13	44

Table 3.: Descriptive statistics for gender, religion and the scores of the sub-scales (EMS and GEB).

level (global vs. local) as within-participants factor and group (derived clusters) as between-participants factors. Finally, the global-precedence effect is explored as a function of religion, gender and social value orientation but only to discuss whether these could have caused the differences in the global-precedence effect.

3.2.2 Findings

One cluster was characterized of mostly non-religious participants with an average score for egoistic motives, higher average scores for altruistic and biospheric motives and reported more sustainable behaviors. The second cluster was characterized of a mix of religious and non-religious participants with higher average scores for egoistic and altruistic motives, average scores for biospheric motives and reported less sustainable behaviors (See tables 3 and 4). These two clusters are referred to as the sustainable group vs. not sustainable group in the rest of the chapter, respectively. Reaction time analysis showed a significant difference between the two groups in responses to local and global targets, $F(1, 84) = 6.766$,

		Sum of Squares	df	Mean Square	F	Sig.
Gender	Between groups	.001	1	.001	.003	.953
	Within groups	21.453	84	.255		
	Total	21.453	85			
Religion	Between groups	1.233	1	1.233	6.633	.012*
	Within groups	15.616	84	.186		
	Total	16.849	85			
Egoistic Motives	Between groups	47.120	1	47.120	18.51	.000**
	Within groups	213.758	84	2.545	7	
	Total	260.879	85			
Altruistic Motives	Between groups	9.954	1	9.954	5.365	.023*
	Within groups	155.858	84	1.855		
	Total	165.812	85			
Biospheric Motives	Between groups	7.823	1	7.823	3.686	.058
	Within groups	178.285	84	2.122		
	Total	186.108	85			
General Ecological Behavior	Between groups	1080.925	1	1080.925	53.20	.000**
	Within groups	1706.575	84	20.316	5	
	Total	2787.500	85			

*Significant group difference; * p < .05, **p< .01.*

Table 4.: ANOVA's showing which of the classifying variables were significantly different between the two clusters.

$p < 0.011$, MSE = 30278.446; and $F(1, 84) = 10.561$, $p < 0.002$, MSE = 33354.727, respectively. Global-precedence effect was notably larger for the sustainable group than it was for the not sustainable group, showing an apparent trend approaching significance: $F(1, 84) = 3.491$, $p < 0.065$, MSE = 5686.462 (See table 5). There were no significant differences between the two groups for social value orientation nor gender: $F(1, 70) = .145$, $p < 0.705$, MSE = .060 and $F(1, 84) = .003$, $p < 0.953$, MSE = .255, respectively. Though, there was a significant difference between the two groups for religion, $F(1, 84) = 6.633$, $p < 0.012$, MSE = .186.

3.2.3 Discussion

The results in this study show that those who are more concerned about the environment and adopt more sustainable practices, attend more to global features of visual stimuli (i.e., global perception style). Reaction time analysis showed

Variables	Sustainable Group	Not Sustainable Group
Sample N (M:F)	59 (31:28)	27 (14:13)
Age	26.9	26.9
Global targets		
Reaction times (ms)**	727.5 (21.2)	865.4 (21.2)
Error rates (%)	5.5	5.4
Local targets		
Reaction times (ms)**	756.8 (20.3)	861.9 (20.3)
Error rates (%)	2.8	3.6
Global Precedence		
Reaction times (ms)*	29.2	-3.5

*Standard errors are presented in parentheses. Significant group difference; * p =.065, ** p< .01.*

Table 5.: Demographic characteristics and performance on global and local targets.

a significant difference between the two groups in responses to local and global targets. The global-precedence effect between the two groups was marginally significant. This can imply that adopting sustainable practices might have long-term impacts on perceptual processes or vice versa, in which three cases are likely; (1) a sustainable lifestyle, or living in an environment that supports it, could lead to a more global attentional bias; (2) a sustainable lifestyle is more attractive to people with a more global attentional bias; or (3) as findings in this chapter do not claim for causality, the link might also be (and most likely) bidirectional or interactive. If cases 2 or 3 are true, the observation in this study could support the potential of designing the environment in such a way it directs our perception towards a more global style to motivate or support sustainable practices.

However, there are some considerations. Firstly, previous research has shown that other factors cause perceptual differences, such as gender, religion, social relations and culture (i.e., Westerners vs. East Asians). Although, these variables were not controlled in this study, all participants were either from a Western country or were currently living in a Western country for some time. Also, there were no significant differences between the two groups for social value orientation nor gender. And although, there was a significant difference between the two groups for religion, the global-precedence effect, as a function of religion, shows smaller within-group than between-group differences. On these accounts, gender, religion, social value orientation and culture could be ruled out in influencing the difference.

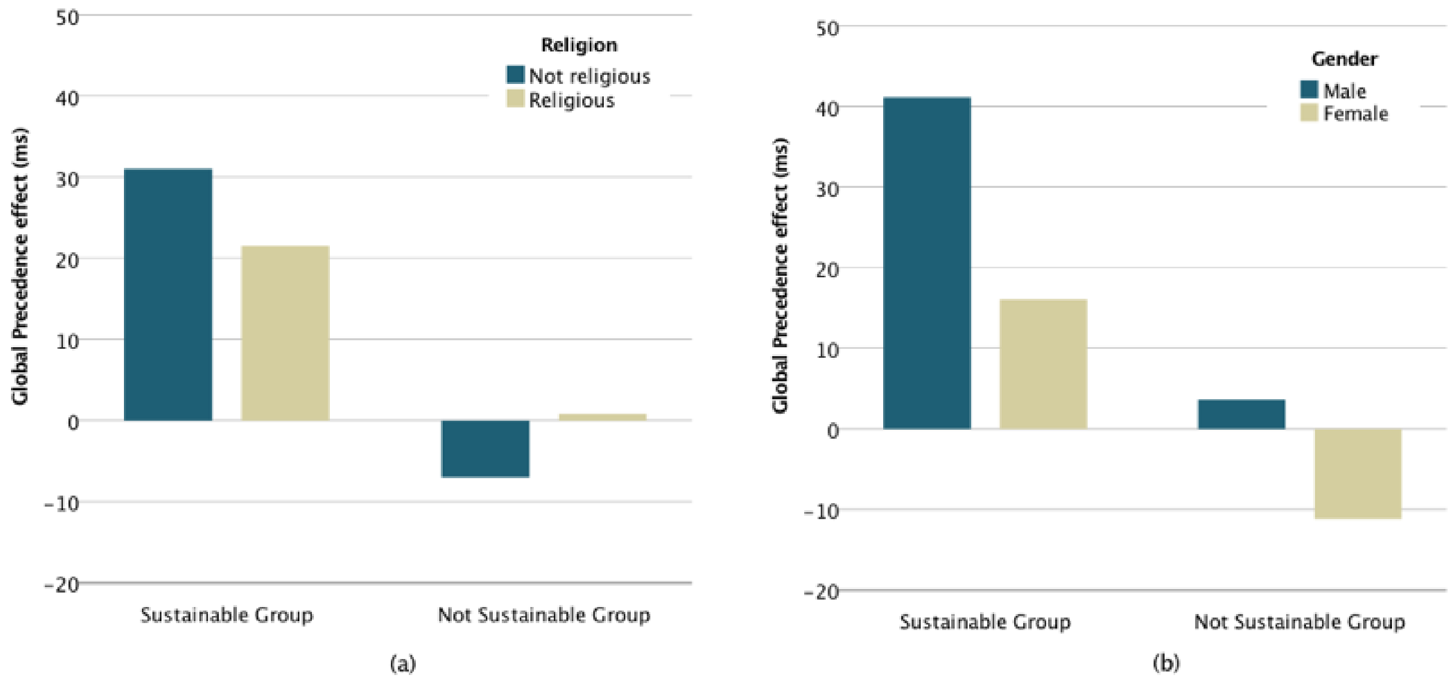

Figure 13.: Mean global-precedence effect as a function of religion (a) and gender (b).

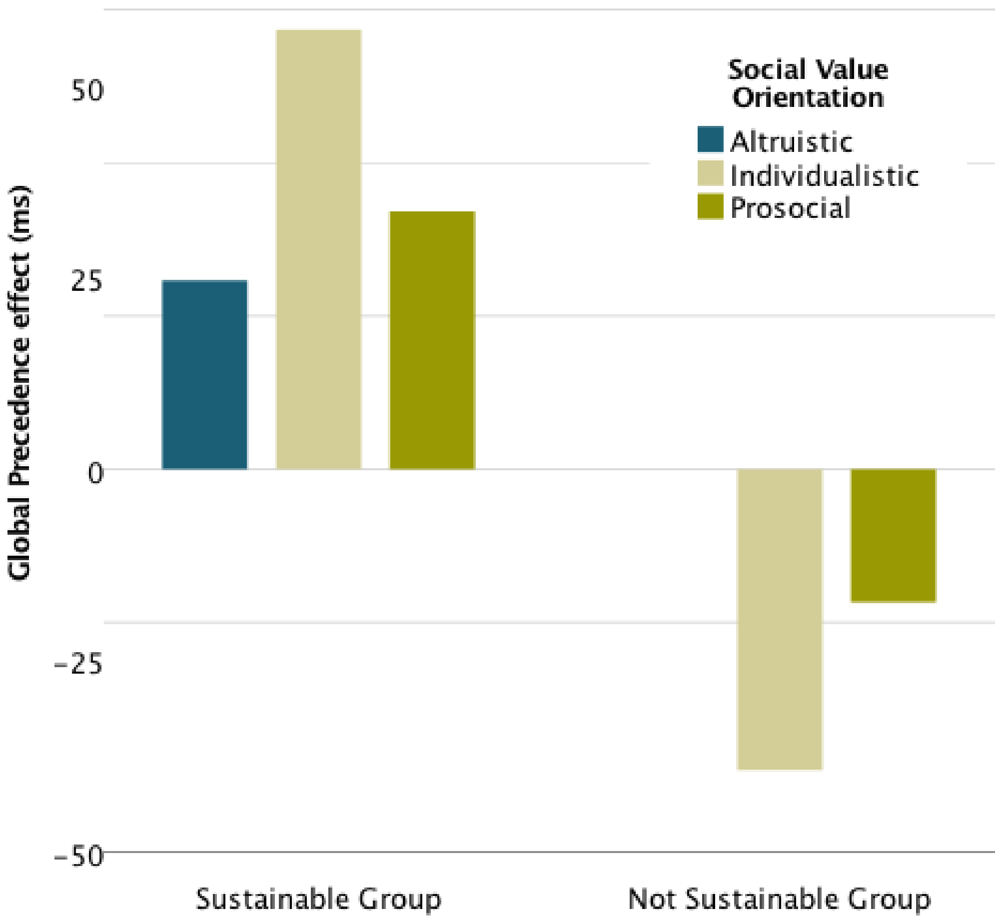

Figure 14.: Mean global-precedence effect as a function of social value orientation.

Limitations

There might have been other confounding factors. For example, IQ, educational style, socio-economic situation, or knowledge were not considered in this study, which brings in some limitations. Future work should include these factors. Furthermore, it could further include observed rather than self-reported behavior. Research has noted limitations with the use of self-reports on environmental attitudes and behaviors (Bratt, 1999). For instance, an observed behavior could be the consumption of actual energy or other resources. Participants could be assigned to a sustainable vs. a non-sustainable group by comparing their consumption patterns with an average for more grounding results. Moreover, the sample size can be larger for more statistical power. Thence, more research is required to confirm the claims presented here.

3.3 CONCLUSION

This study extends previous claims that culture has a significant impact on perception, but challenges it in a way that culture might involve other aspects such as sustainability. Although, most research on perception style has ignored aspects of culture such as religion, recent studies have shown that religion is associated with certain perceptual processes even when culture is controlled for (Colzato et al., 2008; Colzato et al., 2010). Sustainability (as part of a culture) may also be linked to perception style. This study implies a potential fundamental perceptual difference between those who are more concerned about the environment and adopt more sustainable practices from those who are less concerned about the environment and adopt less sustainable practices. A link between perception and sustainability, as explored in this study, could support the idea of designing the environment in such a way it directs our perception towards a more global style, and hence motivate and support sustainable practices. Our environment or technology could, for example, put more emphasis on interdependence and communities.

Part II.

Exploration

4 E-COMATE

In this dissertation, a community-based social system is proposed as a way to raise awareness, emphasis interdependence and support global perception. As part of this system, a concept is explored based on a commonly used strategy in sustainability research, eco-feedback. Eco-feedback usually aims at increasing awareness of resource use to encourage conservation. It provides consumers information about past behaviors as a basis for improvements. However, eco-feedback has not yet given full attention in the context of food waste. In this chapter, E-COmate is introduced, its design rationale, development, and evaluation in a pilot study. E-COmate is a system that captures and visualizes domestic food waste data for more readily comprehensible and accessible information within a home environment.

4.1 PERSUASIVE SUSTAINABILITY

One research field that could provide support in raising awareness and knowledge without requiring cognitive effort from consumers is persuasive sustainability. Persuasive sustainability was introduced by Fogg, who suggested to use computers as persuasive technologies to support environmental sustainability. He defines persuasion as "an attempt to shape, reinforce, or change behaviors, feelings, or thoughts about an issue, object, or action" (1998). Since then, environmental sustainability has gained popularity in HCI, especially in the fields of energy, fuel and water usage. However, in a recent review by Brynjarsdottr et al. (2012), none of the papers found on persuasive sustainability focused on

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This chapter contains parts published in:
Lim, V., Jense, A., Janmaat, J., and Funk, M. (2014). Eco-Feedback for Non-Consumption. *In Adjunct Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing* (pp. 99 - 102). New York, NY: ACM Press.
Lim, V., Funk, M., Rauterberg, M., Marcenaro, L., and Regazzoni, C. (2015). E-COmate: What's your non-consumption? In I. Rojas, G. Joya and A. Catala (eds.), *Advances in Computational Intelligence* (pp. 486 - 499). New York, NY: Springer Publisher.
Lim, V., Bartram, L., Funk, M., and Rauterberg, M. (2017). To Eat or Not to Eat: An evaluation of the Impact of Eco-feedback in a Student Residence. *In ACM Transactions on Computer-Human Interaction*. New York, NY: ACM Press (under review).

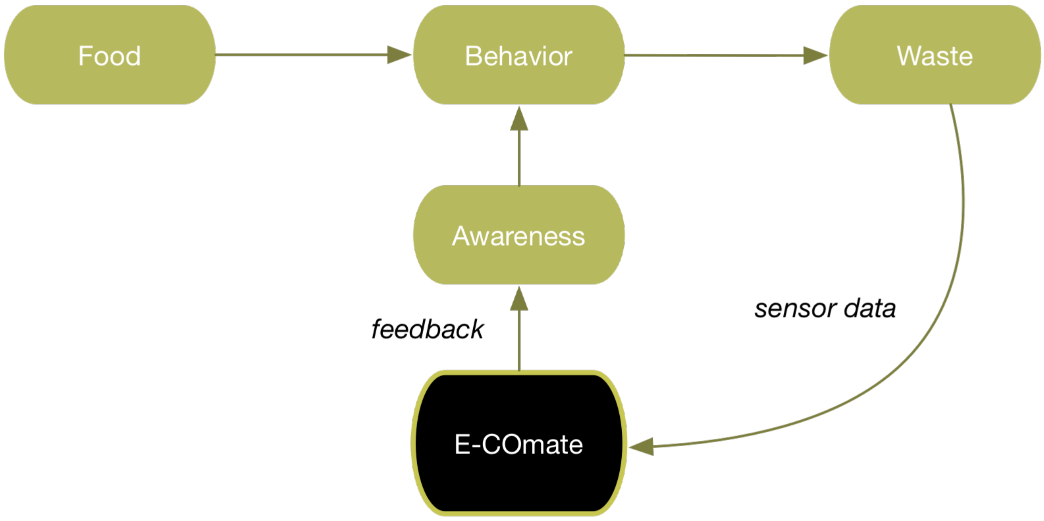

Figure 15.: The output value (i.e., food waste) helps controlling the next output value.

food waste. Instead, energy consumption was the most commonly identified issue, a topic which was addressed in half of the papers reviewed. Of the remaining papers, half involved water consumption, printing paper, and gasoline. The remaining papers were about making green transportation choices, improving indoor air quality, reducing CO_2 emissions, or are not tied to any one specific topic. This shows the need of targeting food waste in current sustainability research. In this chapter, a concept is introduced that draws on a common influence strategy in persuasive sustainability research to increase awareness and to encourage conservation but so far mainly applied in other domains.

4.2 ECO-FEEDBACK TECHNOLOGY

A commonly used strategy in sustainability research is based on the principle of feedback, eco-feedback. Feedback is the process in which the output of an action is 'returned' (fed-back) to modify the next action (See figure 15). It is considered essential for regulatory mechanisms and inherent to all interactions, whether human-to-human, human-to-machine, or machine-to-machine. Eco-feedback aims at increasing awareness by automatically sensing peoples' activities and feeding related information back through computerized means (Froelich et al., 2010), particularly to foster positive attitudes towards sustainability and hence the adoption of sustainable behaviors (Pierce et al, 2008). With eco-feedback, hidden environmental information and behavior patterns are first collected and then replaced with more accessible and understandable information (Holmes, 2007). The reasoning behind eco-feedback is that people understand

and agree to the moral behind the feedback, adopt similar mindsets, and act accordingly once they are more aware of the systematic effects of their everyday actions. Eco-feedback is based on the hypothesis that most people lack understanding or awareness about how their everyday behaviors affects consumption patterns and hence the environment.

However, eco-feedback technology has been generally used for other types of consumption such as residential electricity usage, water usage, transportation, carbon tracking, recycling behavior, and paper use, with residential electricity usage as the most common target (Froehlich et al., 2010 and Brynjansdottir et al., 2012). This emphasis could reflect the impact that electricity usage behaviors have on the environment as well as the ease with which energy usage can be automatically sensed. On the contrary, food waste cannot be easily sensed and is more complex to define, which might have accounted for the lack of research in the application of eco-feedback on food waste. So far, little attention has been paid on how to apply eco-feedback on reducing household food waste with the prospective to increase awareness and lower the impact of every day food-related decision-making on the environment. Although eco-feedback is generally used for other types of consumption, its impacts on food waste and related behavior is rarely studied. Another reason why eco-feedback might not have been applied to food waste is because it has been argued to fail in providing the user with action possibilities (Brynjansdottir et al., 2012; Maitland et al., 2009), and is therefore considered less successful. But with little to no research, this limitation should not be immediately generalized to the field of food waste which is fundamentally different from energy or water usage. Eco-feedback could support reflections and motivate actions implicitly or indirectly. It could also be used to complement or further motivate the adoption of other mechanisms such as actionable suggestions (discussed in *Chapter 7*). Moreover, eco-feedback has been proven to work if certain strategies are adopted: e.g., when a goal is activated or a comparison is made with others (McCalley, de Vries, and Midden, 2011; Midden and Ham, 2013; Foster and Lawson, 2013; Odom et al., 2008).

Despite the limitations discussed above, this work focuses on eco-feedback for the following reasons: (1) Consumers are currently unaware of the amount or value they waste. However, this is likely to be necessary information to motivate consumers towards the next step, action. Eco-feedback could support consumers with situational information cues that can constantly remind and inform them (considering the habitual and unconscious nature of food waste behaviors), without requiring much time and cognitive effort. These subtle reminders might then lead to a certain degree of automatic and systematic behavioral adaptations where old habits are broken and new ones are created (de Vries, Aarts and Midden, 2011); (2) Previous eco-feedback research focused on topics that are, although related, still fundamentally different from food waste. For example, food waste is associated with higher costs than energy or water. It is also a more complex and personal topic with possible solutions outside the domestic environment (e.g., buying less at the grocery store). Therefore, findings from eco-feedback research applied to energy and water consumption should not be automatically generalized to food waste. Furthermore, (3) eco-feedback research has adopted strategies that were found to be successful. These are discussed next.

4.2.1 Use of metaphors

Researchers have explored ways to inform consumption by using metaphorical instead of volumetric units to enhance understanding. For example, they have explored the use of everyday objects as metaphors such as the number of jugs and oil trucks for water usage instead of number of gallons or liters (Froehlich et al., 2012). In a recent study, carbon weight was introduced as an indication of environmental health visualized on a bathroom scale (Kuo and Horm, 2015). For food waste specifically, metaphors could be the number of landfills or calories used for the production of the food that is wasted, the number of people that could have been fed, or how many earths we need if everyone would continue current wasteful behaviors. Table 6 presents some more examples of metaphors used in previous literature.

4.2.2 Use of social influence strategies

Another design aspect is the inclusion of social comparison information used to advance the impact of eco-feedback visualizations. We seem to compare ourselves to others to find out how we are doing when objective measures for self-evaluation are unavailable (Festinger, 1954). This allows us to see what the norm is in our group and to receive social approval for our behaviors. These principles on norm activation and social approval were found to be successful in influencing consumers when facilitated through technology and to support sustainable practices (Midden and Ham, 2013). Additionally, social comparison could trigger consumers to engage in a friendly competition. Previous studies have shown that consumers are more motivated to save energy when they are able to compare with others (Foster et al., 2010; Odom, Pierce, and Roedl, 2008). Therefore, eco-feedback research often uses social comparison as an influence strategy.

4.3 DESIGN RATIONALE: ECO-FEEDBACK OF NON-CONSUMPTION

E-COmate is an augmented bin that captures and visualizes domestic food waste data for more readily comprehensible and accessible information that can be used within a home environment. Researchers have argued that technologically-enhanced feedback could be an important agent of change (Mozo-Reyes et al., 2016; Midden et al., 2008). E-COmate shows consumers their food waste amounts within their own kitchen environment, with the intention to elicit reflection on what it means to waste food on a daily basis without the requirement of cognitive effort. E-COmate is designed to impact consumers in their immediate environments relevant for the food practices at hand, to remind them on a daily basis, and to support actions towards their goal of reducing food waste. It aims at breaking old habits to create new ones (de Vries et al., 2011).

In the design of E-COmate, two main design aspects or commonly adopted strategies were considered. One design consideration was to use a metaphor to visualize food waste (i.e., as opposed to the weight of wasted food) that is expected to be linked to consumers' own daily concerns. The number of servings was selected as a metaphor because it could indicate potential free food or monetary losses. It is speculated that people are generally more common with a 'serving' but with the evidence that metaphors help in a better understanding (Froehlich

Domains	Metaphors
Water consumption	An aquatic ecosystem by Froehlich et al. (2012)
	The number of bottles saved by Elkay[a]
Energy consumption	7000 Oaks and counting by Holmes (2007)
	A clock for energy awareness by Ehrnberger et al. (2013)
	Environmental health visualized on a bathroom scale (energy diet) by Kuo and Horm (2015)
Fuel efficiency	Polar bears by Froehlich et al. (2009)
	Cluster of leaves by Ford[b]

Table 6.: Examples of metaphors used for different domain.

a http://www.elkayusa.com/
b http://smartdesignworldwide.com/work/ford-smart-gauge/

et al., 2012; Kuo and Horm, 2015). Although, financial incentives were found to have short-lived effects and can be counter productive in studies on energy use (Delmas, Fischlein, and Asensio, 2013), whether this applies to food waste is unclear. Financial benefits from saving energy are often quite small compared to household expenses such as food (Wolak, 2011). The second design consideration is the inclusion of social comparison information so that users see how much other groups of users are disposing. This was expected to engage users in social interaction, e.g., such as food sharing within their own group or competition towards the other group. Both design considerations were taken into account in the two prototypes of E-COmate that has been developed.

4.4 PROTOTYPE 1

The first prototype was build for an initial pilot test, aiming at exploring its impact on awareness, food related decision-making and the desirability of such a system. Findings were used for the next design iteration of the concept and, for more concluding results, in a larger-scale evaluation.

4.4.1 System design

The first prototype consisted of a laptop computer with custom software and a laser-cut wooden enclosure containing an of-the-shelf Dymo M5 USB postal scale, an Arduino microprocessor and additional electronics (See figure 16). For every time a user disposes an item, they could use buttons to indicate the food group (grains, dairy, vegetables, fruits, and animal proteins), whether it was a leftover from a meal, and its quality (bad, possibly bad, good). This information was initially collected only for quantification purposes but could be used in the information fed back to users in future prototypes (e.g., to show what users wasted most). Together with the details on the disposed food, the date, time and weight were stored automatically. The laptop runs a pure-data patch which handles the collection and saving of data into a text-file, as well as the communication with the scale and Arduino. The scale transmits its measurements over USB through the HID protocol via a USB connection with the laptop computer. The Arduino processor reads the buttons and controls the indication LEDs, which is controlled by the laptop through a custom protocol via a serial USB connection (See figure 17 for the software setup).

4.4.2 Interface design

Subsequently, eco-feedback is provided through a display that visualizes food waste in number of meals. In this case, every 700 grams of disposed food equals

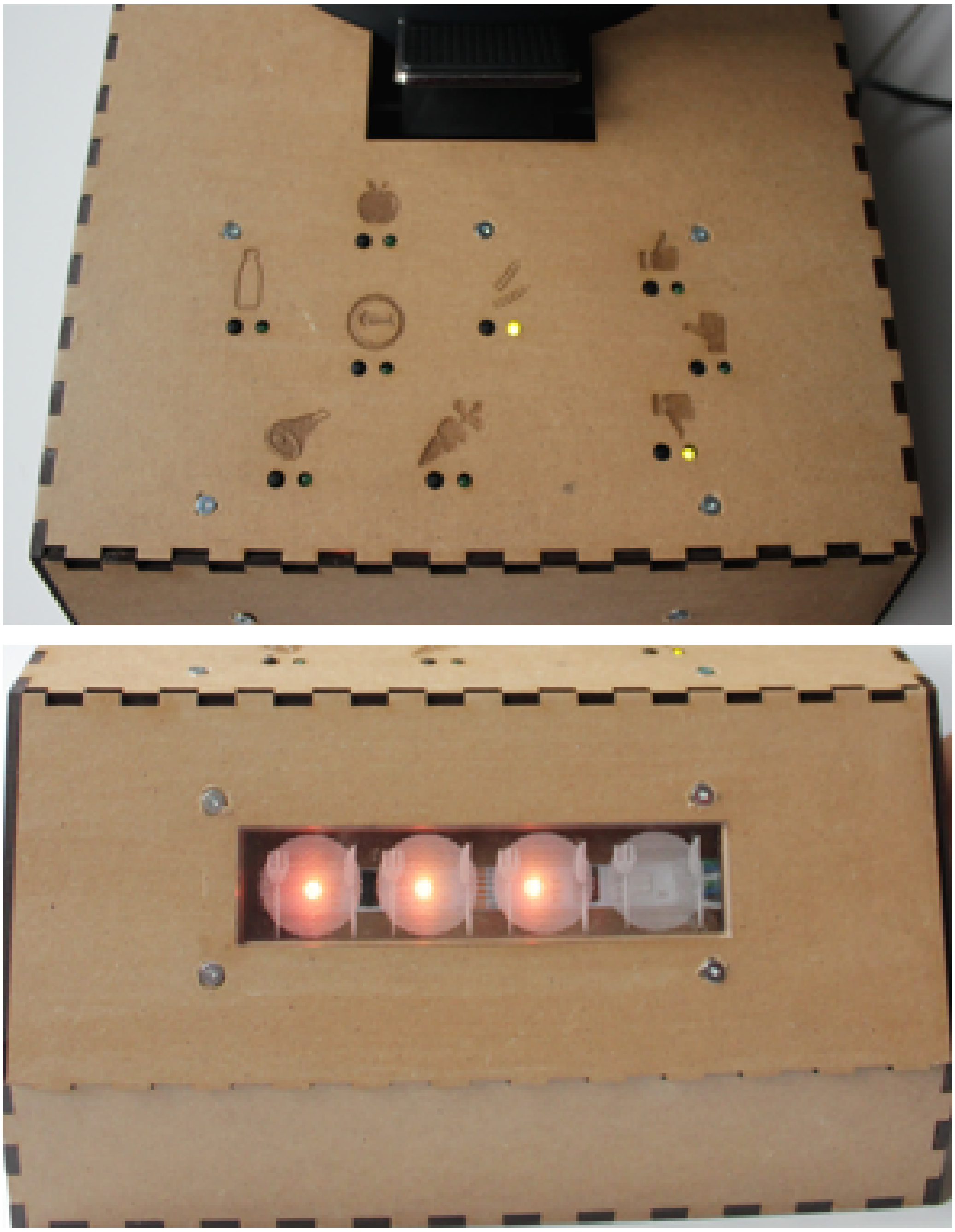

Figure 16.: The first prototype of E-COmate. The top image shows the buttons for food waste types and indicators (e.g., thumbs up and down) for the food quality that is being disposed. The bottom image shows the feedback in numbers of meals (here, with a maximum of 4 meals.)

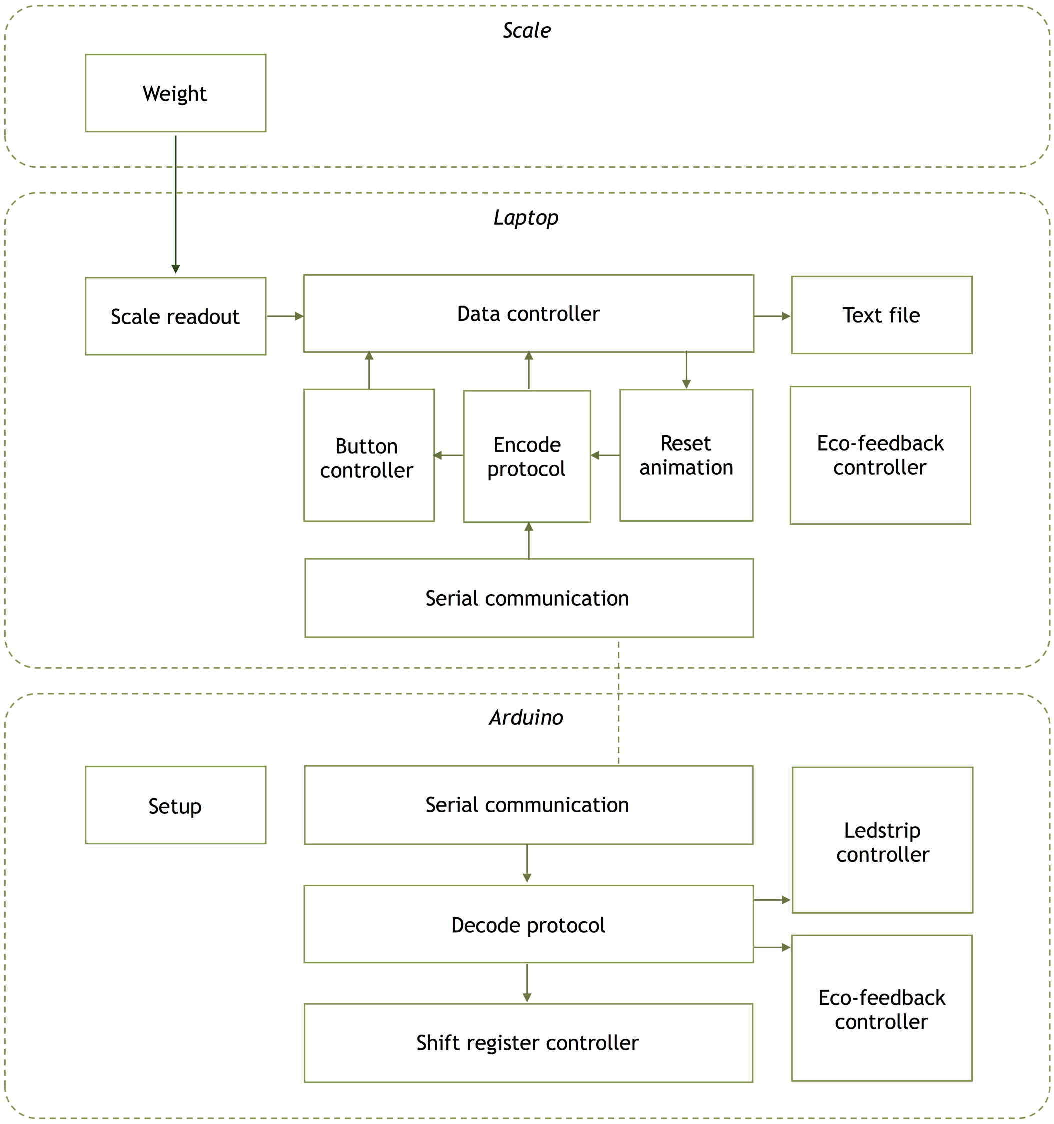

Figure 17.: The high-level model of the E-COmate application for the first prototype.

to one meal. A second dimension of information was provided through the color of the aggregate meals that were disposed to visualize comparison information: red indicated an higher average of daily food waste amounts in comparison to others (negative feedback) and green indicated a lower average of daily food waste amounts in comparison to others (positive feedback). The amount for *others* was based on the average food waste per person per day which is approx. 137 grams according to Thönissen (2010). Therefore, participants could compare their food waste amounts with actual data.

4.4.3 A pilot study

The first prototype was tested in a pilot case study. It was deployed in a student house with four female students who used the system for two weeks continuously. The main aim of the study was to explore the desirability of applying eco-feedback to food waste practices and its impact on reflection and decision-making processes around food.

Methodology

In the first week, participants did not receive interventions in terms of feedback. This week served as a baseline measurement and sensitization to using the prototype. In the second week, feedback was implemented and simulated (i.e., the feedback information was manually changed every day depending on the weight). At the end of each week, participants were asked to fill in a questionnaire to explore the impact of eco-feedback or the lack thereof. The questionnaire items were on how E-COmate impacted individual as well as the groups' food-related behaviors (i.e., planning, purchasing, preparation, and dealing with leftovers). Other questionnaire items were on how E-COmate impacted awareness of overall food practices, the level of motivation to change behavior, and reflection. The questionnaire was set-up using a five-point Likert scale. Answer options ranged from *very much*, *somewhat*, *undecided*, *not really*, and *not at all* (See Appendix C). A paired t-test was conducted to determine if a statistically significant difference existed between answer scores provided after the baseline vs. after the intervention. A research team member was part of the house but presented her role as someone who just had to make sure that the bin was working and all questionnaire were filled. This ethnographic research style allowed for informal observations and discussions: short semi-structured interviews were conducted based on the same questionnaire items, but aiming for more in-depth discussions on *how* they think E-COmate had affected their behaviors.

Findings

Findings are presented in tables 7 and 8. Differences in scores (≥ 1) between baseline and intervention measures were found for planning (M = 2.33, SD = 1.53 and M = 3.33, SD = 1.16, respectively) and preparation (M= 2.33, SD = 1.53 and M = 3.33, SD = 1.16, respectively) on an individual basis, but these were not significantly different, $t(2) = -1.00$, $p = .423$ and $t(2) = -1.00$, $p = .423$. A difference in scores between baseline and intervention measures were also found for dealing with leftovers on an individual basis (M = 2.33, SD 1.53 and M = 4.00, SD = 1.00, respectively) but were also not significantly different, $t(2) = -1.67$, $p = .130$. Although not significant, participants reported to have been saving their leftovers for lunch more during the study than before.

		Baseline Mean	St. Deviation	Intervention Mean	St. Deviation
Individual behavior	Planning	2.33	1.53	3.33	1.16
	Purchasing	1.33	.58	2	1.00
	Preparation	2.33	1.53	3.33	1.16
	Leftovers	2.33	1.53	4	1.00
Group behavior	Planning	3	1.73	3.67	2.31
	Purchasing	2.67	1.16	2.67	1.16
	Preparation	3	1.73	4.33	.58
	Leftovers	4.33	.58	4.67	.58
Awareness		3.67	.58	3.67	.58
Motivation		3.67	1.53	4	.00
Reflection		4	.00	5	.00
Usability		2	1.00	2.33	.58
Overall		3.33	1.16	4	.00

Table 7.: The means for each question item and condition.

At the group level, a difference was found in scores (≥ 1) between baseline and intervention measures for preparation (M = 3.00, SD = 1.73 and M = 4.33, SD = .58, respectively) but was not significant, $t(2) = -1.33$, $p = .184$. Although not significant, participants reported to be more careful in the amount that is being cooked. The intervention did not impact differently than the baseline measures for planning, doing groceries or dealing with leftovers.

Overall, whether eco-feedback was absent or present, the prototype had similar impacts on awareness (M = 3.67, SD = .58 and M = 3.67, SD = .58, respectively) and on motivation (M = 3.67, SD = 1.53 and M = 4.00, SD = .00, respectively). However, participants provided higher scores for self-reflection when eco-feedback was implemented (M = 5.00, SD = .00) in comparison to the baseline measurement (M = 4.00, SD = .00).

Conclusion

These findings show that there is a potential of applying eco-feedback of non-consumed food items for raising awareness and triggering self-reflection, specifically on how individuals plan, prepare food and deal with leftovers. Also, eco-feedback could have impacts on the group in terms of food preparation. For future studies, however, the system software requires further improvements and

		Mean	Std. Deviation	t value	df	Sig.
Individual behavior	Planning	-1.00	1.73	-1.00	2	.423
	Purchasing	-.67	1.16	-1.00	2	.423
	Preparation	-1.00	1.73	-1.00	2	.423
	Leftovers	-1.67	1.16	-2.50	2	.130
Group behavior	Planning	-.67	.58	-2.00	2	.184
	Purchasing	-	-	-	-	-
	Preparation	-1.33	1.16	-2.00	2	.184
	Leftovers	-.33	.58	-1.00	2	.423
Awareness		-	-	-	-	-
Motivation		-.33	1.53	-.38	2	.742
Reflection		-	-	-	-	-
Usability		-.33	.58	-1.00	2	.423
Overall		-.68	1.16	-1.00	2	.423

*Significant group difference; * $p < .05$, ** $p < .01$.*

Table 8.: Paired t-test results summary for each question item comparing the average Likert scale answer results between the baseline and intervention measures. Note: " - " is where t could not be computed because the standard error of the difference is 0.

an evaluation with more participants. For example, the prototype needed to be restarted after once or several use cases which was slightly disturbing for users. The feedback information also needed to be updated manually, so it lacked responsiveness or immediacy. Furthermore, indicating the type of food waste required too much interaction from the user side. Thus, the prototype was not equipped for longer term deployment studies (e.g., in terms of interaction requirements and display features). It needs to be improved to be suitable for long term studies. This is necessary before it can be evaluated with a larger sample size: for statistical analysis the current sample size is too small for meaningful conclusion.

4.5 PROTOTYPE 2

The main focus in the development of the second prototype was to decrease user inputs and to collect and visualize data for a longer period of time. This means that improvements in the system and in the user interface features were required.

It should be noted that for this second prototype, the collection of food waste types (i.e., in prototype 1 this was collected through button presses) was left out as it requires the use of more advanced methods such as additional sensors to keep user-system interactions to a bare minimum. A future prototype could, for example, use computer-vision techniques (e.g., like a camera) to automatically identify the type of food been thrown in the bin. However, this is not covered in this dissertation.

4.5.1 System requirements

The requirements for prototype 2 are divided for *system* and *interface design features*. These requirements were considered essential for conducting a user study where interactions between system and users are kept at a minimum, and for answering our research questions.

- **System features.** To ensure weight changes are recorded, raw sensor data (i.e., weight) should be recorded periodically and stored automatically in a local memory as well as on a server with a time stamp. System processes such as receiving data from the scale, and sending data to a server should be traceable and visible. The data that is collected should be available online for analysis as well as remote monitoring. These requirements would help identify system failures and trigger quick reboots of the prototype during deployments.

- **Interface design features.** The data should be visualized on a display, such that it is visible at-a-glance in a location relevant to food-related activities. To emphasize the social environment, the visualization should include social comparison as influence strategy: for research purposes and to control for the type of feedback (i.e., positive vs. negative), social comparison information could be generated from users actual waste. Overall, the prototype should be protected with a casing to prevent food dirt as well as displacements of the different parts.

4.5.2 System design

Based on these requirements, the second prototype consist of an of-the-shelf Dymo M5 USB postal scale that measures the weight periodically and transmits its measurements (only when there is a change in the weight) via a USB connection to a Raspberry Pi (See figure 18 for the hardware parts). The Raspberry Pi includes a Wi-Fi module which handles the collection and saving of data into a server, as well as the communication with the scale. System processes were visible with led lamps which indicated when the program has started (red), when the scale is connected to the Raspberry Pi (orange) and when the Raspberry Pi

Figure 18.: Parts of the prototype: a Demo scale, tablet and a Raspberry Pi.

measured a stable weight and uploads it to a server (green). The data in the server can then be exported to an excel or text file for analysis. The data is further visualized on an Android application programmed in Java.

4.5.3 Interface design

For the presentation of the data, two simple visualizations were developed. For the first visualization (See figure 19), numerical values and a symbolic visualization of wasted foods were used. Numerical values were provided for the number of days and the amount of potential servings wasted by users and others (e.g., social comparison information) since the start of usage. The symbolic visualization showed the relative difference between zero waste (a black circle in the center of the display), the amount other people are wasting (a blue circle in the center of the display), and participants' own current waste (a colored ring also in the center of the display). The black and blue circles representing zero waste and the amount of waste other people have generated were kept constant for simplicity and consistency. The ring representing participants' amount of waste changes color and size depending on whether the feedback was positive (green and smaller than the blue circle) or negative (red and larger than the blue circle) in comparison with others. Additionally, users can interact and express feelings towards the feedback by pressing one of the emoticon buttons. Universal emo-

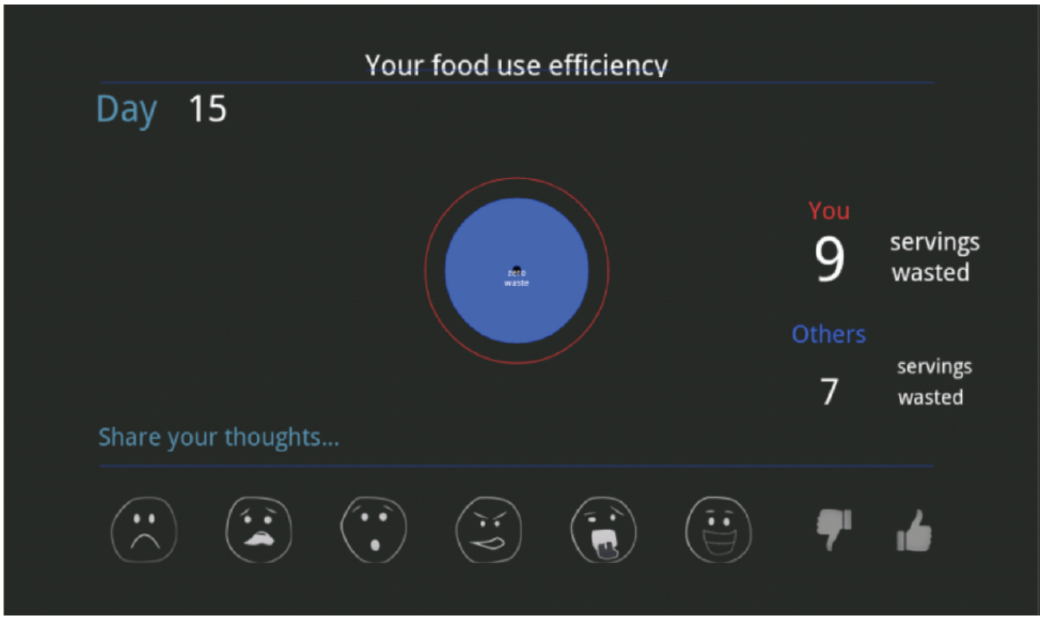

Figure 19.: Visualization 1 with only social comparison information.

tions were used such as sadness, surprise, disgust, fear, anger and happiness and a thumbs up (i.e, "like": "I like this amount of waste" (in comparison to others)) and a thumbs down (i.e, "dislike": "I do not like this amount of waste" (in comparison to others)) in case users do not want to express emotions. The second visualization only included numerical values, but with the addition of the daily average and the total number of potential servings wasted in the past 24 hours (See figure 20). For user interactions, the display includes only the thumbs up and thumbs down buttons. The display also includes a note with the definition of a serving (i.e., one serving for each 200 grams). In both visualizations, social comparison information was generated by taking a random percentage between 40 - 110 percent of users' actual total weight. Hence, it was set in such a way it would show mainly negative feedback to *all* users. This was done to control for the nature of feedback to all groups.

4.5.4 Improvements and limitations

The second prototype is improved from the first in the sense that (1) it is more compact, (2) it has Wi-Fi connection, (3) it provides visibility for system failures, (4) and it has an improved display design including more information which automatically updates based on the weight. Despite these improvements, it still has some technological limitations. For example, data collection depends on Wi-Fi connection: whenever this is temporarily off, data won't be collected. Furthermore, the scale cannot reset to zero automatically when the bin is getting emptied. This should be done manually for higher accuracy and hence requires

Figure 20.: Visualization 2 with social and self comparison information.

users' effort. Also, the data that is collected could be other than wasted foods: as users are not required to indicate the food waste type as in the first prototype, it might be more likely for non-organic materials to end up in the bin. These limitations were taken into account during the deployments. In the following chapters, the second prototype was deployed (with visualization 2 in *Chapter 5* and with visualization 1 in *Chapter 7*). In each deployment study, different enclosures were used to protect the hardware.

5 IN THE FIELD

The second prototype of E-COmate with visualization 2 was deployed and evaluated in a student residence for a period 8 weeks. The aim in this deployment study was to see whether a system like E-COmate could impact food waste patterns and awareness, to what extend it engages consumers, and how it should be designed further. In this chapter, the context for evaluation and the adopted methodology are discussed. For this deployment, a mix of quantitative and qualitative methods were adopted. The findings provide information on design implications for E-COmate and eco-feedback for food waste in general.

5.1 THE ZERO WASTE INITIATIVE

The European Commission has acknowledged its intention to move the EU towards Zero Waste. With local zero waste groups and more than 300 European municipalities, Europe is at the forefront of waste management practices and have commended to new benchmarks for new recycling targets of 70% by 2030, mandatory separate collection of organics by 2025, and food waste reduction by at least 30% by 2025[1]. Moreover, in the United States, all companies and institutions that produce more than 1 tonne a week of organic waste are banned from sending it to landfills since 2014. Recently, also the city of Vancouver banned food scraps from disposal as garbage as of January 2015. Vancouver aims at increasing the regional recycling rate to 80% by 2020. To match with these developments, the Simon Fraser University (SFU) located in Vancouver introduced the Zero Waste initiative as part of their Sustainability Strategic Plan. Along with this initiative, SFU placed Zero Waste stations in interior and public spaces of SFU,

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This chapter contains parts published in:
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Lim, V., Bartram, L., Funk, M., and Rauterberg, M. (2016). To Eat or Not to Eat: An evaluation of the Impact of Eco-feedback in a Student Residence. *In ACM Transactions on Computer-Human Interaction*. New York, NY: ACM Press (under review).

1 https://www.zerowasteeurope.eu/tag/reuse-targets/

and only recently also in other areas such as SFU's housing and residences. Zero Waste stations are color-coded bins with matching signage as shown in figure 21. Their reasons for including housing and residences was to provide consistency for on-campus students and to decrease confusion on how to divide waste. The Zero Waste stations were implemented also because of high volumes of waste, in particularly food waste. For example, in December 2014, an audit showed that only 8% of all disposed materials (by weight) was landfill garbage, while 92% were either recyclables or organic waste (i.e., including food). A third of the total waste was identified as organic waste, which indicates a clear need to raise awareness of food waste or increase in recycling rates among students. Raising awareness or recycling rates are expected to help reduce financial penalties associated with rejected loads or contamination. With these developments and goals, SFU provides a context for a case study to deploy and evaluate the impact of E-COmate, and explore how it should be designed further.

Figure 21.: A 3-stream Zero Waste station for organic waste (green), mixed recyclables (blue) and landfill garbage (black) that is introduced to the SFU housing and residences, among which the McTaggart-Cowan Hall.

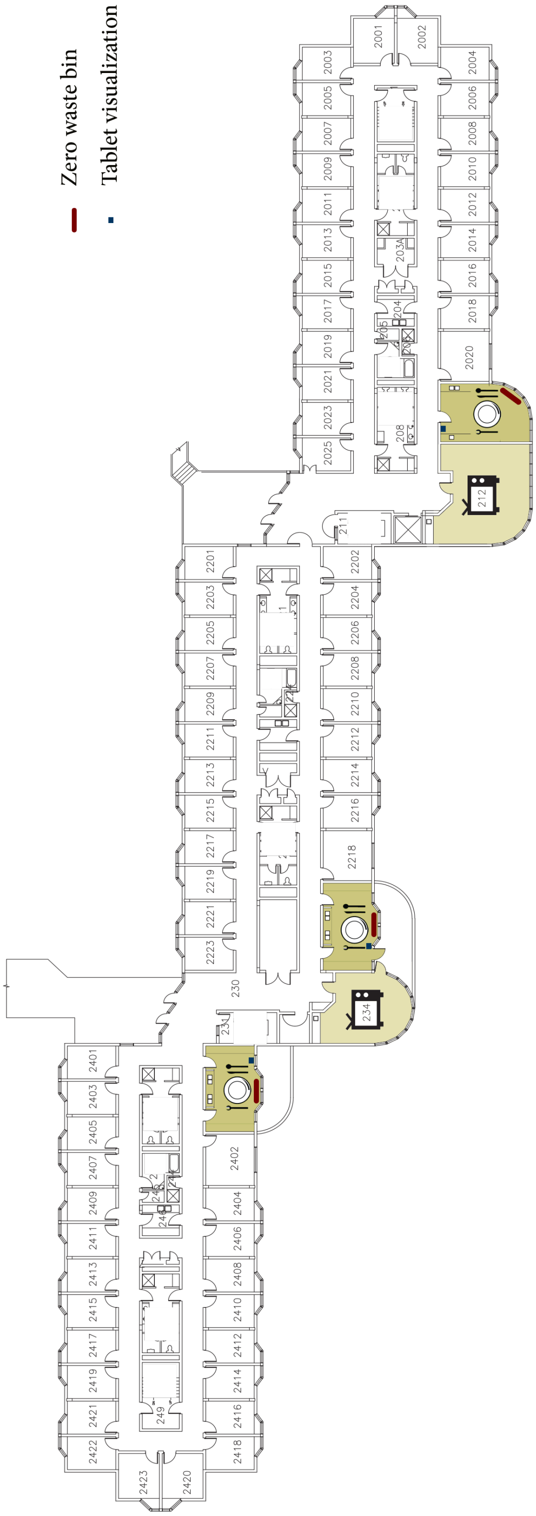

Figure 22.: A floor plan of the McTaggart-Cowan Hall.

5.2 A CASE STUDY: THE MCTAGGART-COWAN HALL

A residence at SFU introduced with the Zero Waste stations is the McTaggart-Cowan Hall. Built in 1985, the McTaggart-Cowan Hall is a traditional style residence with a maximum capacity for 200 students with private bedrooms but shared washroom, laundry, living room and kitchen facilities (See figure 22 for the floor plan). The building with a total of 6 living rooms and 9 kitchens are divided between 3 floors, the 2000 level, 3000 level and the 4000 level. Most inhabitants in the McTaggart-Cowan Hall are undergraduates from second up to their fourth year of study and a smaller amount of residences are graduates. From early September 2015, SFU placed 3-stream Zero Waste stations (i.e., for organics, mixed recyclables, and landfill garbage), signage and information in 4 of the kitchens (i.e., 3 on the 2000 level and 1 on the 3000 level). And as of January 2016, Zero Waste stations were placed in the remaining kitchens, making it a suitable setting to deploy E-COmate in a real environment for a semi-controlled experiment. E-COmate was deployed and evaluated in the McTaggart-Cowan Hall to see whether eco-feedback could (1) impact food waste patterns and (2) awareness, (3) to what extend it engages residences in reducing food waste, and (4), to explore how it should be designed further to effectively motivate sustainable behaviors.

5.2.1 Methodology

Study design

E-COmate was deployed in the McTaggart-Cowan hall for 8 weeks (i.e., end-February to end-April) after 2 week of baseline measures (i.e., only visual inspections from mid-February to end-February). The length of the study depended on the fact that there is a change of students every other term. The 9 kitchens were divided into two groups: a control group (i.e., without E-COmate installed) and an intervention group (i.e., with E-COmate installed). E-COmate was installed and embedded in the green compartment of the 3-stream Zero Waste station in 4 kitchens (i.e., 3 on the 2000 level and 1 on the 3000 level) as shown in figure 23. And 5 kitchens served as the control group. During the deployment, all captured data with E-COmate was visualized on a tablet computer that was protected with an anti-theft lock and mounted to a wall near the Zero Waste station as shown in figure 24. In the first month of the study (i.e., 4 weeks), the tablet visualization showed no social comparison information, but was later added in the second month. Although, social comparison information was generated from users' actual weight, participants were informed that social comparison information was coming directly from another group of participants to trigger competition. This study design allows for between-subjects comparisons (i.e., control vs intervention group) as well as within-subjects evaluations of the prototype (i.e., without vs. with social comparison information).

Data collection and analysis

To evaluate the impact of E-COmate, a mix of quantitative and qualitative methods were adopted: visual inspections, an online questionnaire, real-time measurements and semi-structured interviews. The visual inspections (i.e., waste audits) were conducted two times a week for a total of 10 weeks in all kitchens but only for the organic waste compartment. During the last weeks, all inhabitants from both the control and the intervention groups were asked to participate in an online questionnaire to gain insights in their food-related behaviors and perceptions. Only in the intervention group, data was collected through the prototype (i.e., real-time weights), which was also used as input for the tablet visualizations. User interactions with the tablet visualizations were collected for 'like' or 'dislike' button presses. At the end of the study, semi-structured retrospective interviews were conducted with inhabitants from the intervention group to gain insight in how E-COmate have impacted them and to explore further design implications. Next, the methods are discussed in more detail including participants demographics, the procedures and analysis.

Visual inspections. The data collected during the visual inspection represents items coming only from inhabitants who were using the kitchen. In theory, as

Figure 23.: From left to right: The first image shows how the Demo scale is resting on top of a standard and covered with a plate (i.e., this whole unit is placed inside the green compartment). The second image shows a top view of the scale and a Raspberry Pi inside the green compartment without the plate cover. The third image shows a top view with the plate cover and the scale underneath it. The plate cover allows for rebooting the scale and visibility of system status.

Figure 24.: A tablet computer mounted with an anti-theft protection to a wall nearby a Zero Waste station.

SFU offers meal plans, a selection of inhabitants would almost never be using the kitchen for cooking. During the period of the study, 74 out of 200 inhabitants had a meal plan. Hence, there should be a total of 126 inhabitants who used the kitchen mostly; an average of 14 inhabitants per kitchen. Based on observations, every kitchen was being used. The procedure of inspections was as follows. Twice a week on Tuesday and Thursday mornings, all organic waste of each Zero Waste station were visually inspected for 10 weeks, 2 weeks of baseline measures and 8 weeks with E-COmate deployed. A total of 20 inspections were done for each kitchen (i.e., 180 in total). During these inspections, the type and weight of the disposed items were documented. These items were broken down into 6 categories. These categories were edible or once edible vegetables and fruits, meat and fish, grains and starches, potentially non-edible parts such as peels, tea bags, bones, and egg shells, non-food organics such as paper towels, and contamination such as plastics or glass. During these inspections, peels that are commonly eaten were considered edible (e.g., potato peels opposed to citrus or avocado peels). The content collected from each kitchen was laid out on a plastic sheet and captured with a camera for details such as whether disposed items were cooked or uncooked ingredients, and once edible or still edible. Visual inspections are in general more reliable to measure wasted foods than other methods such as a survey. Visual inspections, for example, do not depend on the limitations of memory recall. Furthermore, visual inspections do not have to rely on Wi-Fi availability or system accuracies. It collects ground truth data. To analyze the collected waste data, paired samples t-tests were conducted to compare the amount of generated waste (i.e., for each waste type) by the inhabitants during the first 2 weeks (i.e., baseline) and the last 2 weeks. These where then explored for differences between the intervention and the control group. Paired samples t-tests were also conducted to compare the amount of generated waste (i.e., for each waste type) by the intervention group during the last 2 weeks of using E-COmate without social comparison information (i.e., week 5 and 6) and the last 2 weeks of E-COmate with social comparison information (i.e., week 9 and 10). Only the last 2 weeks were included in the analysis to rule out innovation effects. Finally, paired samples t-tests were conducted to compare the amount of generated waste by the inhabitants that were edible during the first 2 weeks (i.e., baseline), week 5 and 6, and the last 2 weeks. These where also explored for differences between the intervention and the control group.

Online questionnaire. Inhabitants were personally approached in the last weeks of the study at the entrances and in the shared spaces of the McTaggart-Cowan Hall and asked for their participation in the short online questionnaire. The questionnaire approximately took 2 to 5 minutes to fill out. Inhabitants were given a link to the questionnaire which they could open in their own browser. This link was also posted online in the resident floors' Facebook pages. The questionnaire included demographic questions such as gender and age, general questions about food-related behaviors (i.e., the frequency of food purchases and cooking) as well as food waste-related behaviors (i.e., whether forgetting, past food expiration date and overbuying were common reasons for them to waste food), questions to explore their perceptions on wasted amounts (i.e., their estimation of food waste amounts in weight, in number of servings, in the amount of water necessary for the production of the wasted foods and in comparison to other people), their level of interest in saving food from being wasted, and whether they were interested in adopting technology in their house to raise awareness on food waste practices (See Appendix D). The aim of this questionnaire was to gather background information of inhabitants and their attitudes towards food-waste related technology. A total of 45 respondents filled out the online questionnaire: 46% were in the intervention group. The average age of these respondents was 21 (SD = 1.6), and 58% were female. Over 70% do groceries more than once a week and cook more than 2 or 3 times a week. About 42% agreed or strongly agreed on tending to overbuy food that get wasted, about 50% agreed or strongly agreed on commonly throwing out food because of passing expiry dates, and about 28% agreed or strongly agreed on commonly throwing away forgotten leftovers (See figure 25). Respondents reported to waste vegetables and fruits (over 60% of the total waste) most often. Overall, 58% think their waste is lower or much lower in

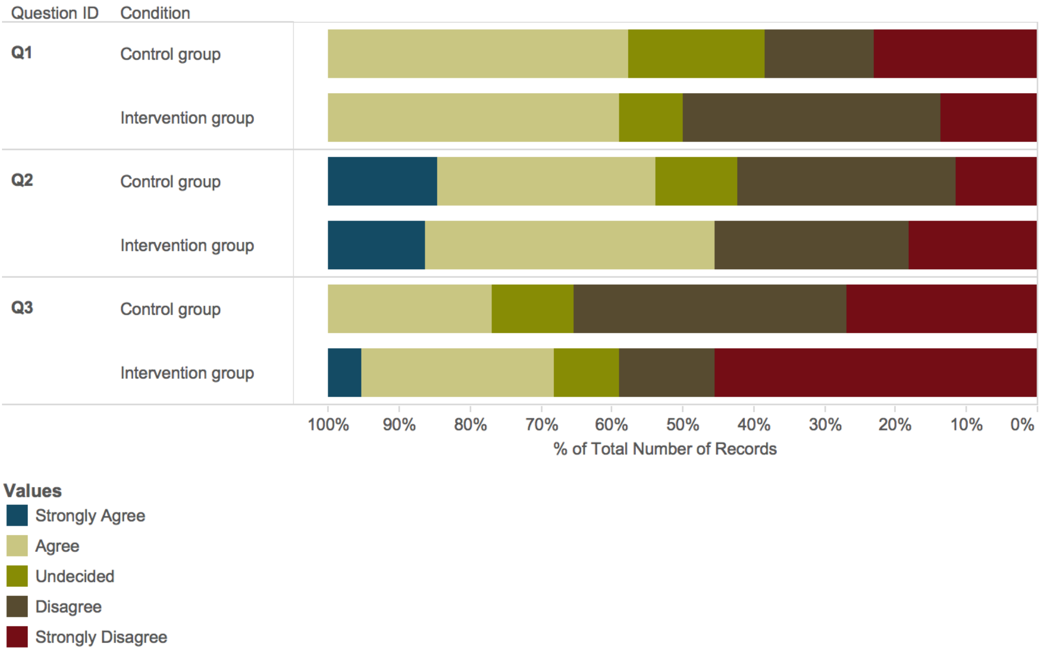

Figure 25.: The level of agreement in both groups for food waste behaviors. Q1: I tend to overbuy food that get wasted, Q2: I commonly throw out food because of passing expiry dates, and Q3: I commonly throw away leftovers that I forgot I have.

comparison to other people. Over 60% of the respondents is somewhat or very concerned in the issue of food waste in relation to global food security, and over 70% is somewhat or very interested in actively saving food from being wasted is. Over 60% would adopt technology in their homes to raise awareness on food waste practices.

Real-time monitoring. Only participants in the intervention group were monitored in real-time through E-COmate. E-COmate collects weight data in real-time, which was used as input for the tablet visualizations for the entire period of 8 weeks. The prototype was rebooted on the days of visual inspections to assure accuracy. Moreover, one of the inhabitants was recruited to help reboot the system whenever necessary: the prototype could turn off accidentally in case of Wi-Fi unreliability or system failures. The data was analyzed for the total 'like' (i.e., "I like this amount of waste.") and 'dislike' (i.e., "I don't like this amount of waste.") button presses on the tablet visualization to explore users engagements throughout the study. Paired t-tests were conducted to compare the total number of button presses when the display did not show social comparison information and when the display did show social comparison information. Paired t-tests were also conducted to compare the number of 'like' vs the number of 'dislike' when the display did not show social comparison information as well as when the display did show social comparison information.

Interview outline. In the last weeks of the study, inhabitants from the intervention group were personally approached in the kitchens and ask for their participation in a retrospective semi-structured interview. A total of 9 inhabitants participated in the semi-structured retrospective interviews (as the online questionnaire was anonymous it is unclear whether these 9 have also filled out the questionnaire). These participants reported to have checked the visualization every time they were in the kitchen or at least 3 times a week. And overall, cooking was mentioned to be more of an individual activity: Inhabitants commonly cook for themselves but sometimes eat their own food together.

The interview is split in two parts. *Part 1* includes open questions to explore the impact of E-COmate. Participants were asked what they liked about E-COmate, their main issue with it, if there was any change E-COmate could have had impact on, and how it had impacted their thoughts about food waste in general as well as their food practices (i.e., the way they plan around food, do groceries, prepare food, and deal with leftovers, individually as well as collectively. In *part 2* of the interview, a number of display visualizations were presented with different design dimensions to collect participants opinions in its usefulness and to which extend it would motivate them to prevent food waste. An introduction to the display dimension and the findings from this second part of the interview is further discussed in *Chapter 6* and is not included in this chapter.

The interviews were recorded so that interruption of conversations was limited as much as possible. The completion time of the interviews was between 20 and 40 minutes. The interviews were transcribed and codes were generated within the overarching themes of research aims (i.e., how E-COmate support in raising awareness, how it impact attitude, how it encourage in active engagements, and how it should be designed), but further not defined a priori. Then, 2 coders received the transcriptions, the codes, and definition of the codes. To assure inter-rater reliability, the 2 coders assigned the provided codes to transcriptions independently. In case of disagreement, items were discussed for inclusion or exclusion. To measure inter-rater reliability, the Fleiss' kappa was applied, which is a statistical measure for assessing the reliability of agreement of a fixed number of raters when assigning categorical ratings to a number of items. In other words, the Fleiss' kappa measures the level of agreement that a certain item or subject belongs to a certain category (Fleiss, 1971). In the findings discussed next, only those categories are included and discussed for which raters came into substantial agreement (i.e., kappa is 0.61 - 0.80). Participants are referred with pseudonyms.

5.2.2 Findings

The goal of the study was to see whether eco-feedback could (1) impact food waste patterns and (2) awareness, (3) to what extend it engages residences in reducing food waste, and (4), to explore how it should be designed further to effectively motivate sustainable behaviors. In answering these questions, data gathered through the visual inspections, questionnaire, the prototype and the interviews were triangulated to gain a deeper understanding.

Observed changes in food waste patterns

Figure 26 shows the distribution of all disposed items by waste type. In both the control and the intervention group, vegetables and fruits, grains and starches, and inedible food parts were thrown away mostly. This is in accordance to what inhabitants reported to waste the most in the questionnaire, but they seem to underestimate the amount of waste for grains and starches. Next, a more detailed overview is provided on the type and quantity of waste the inhabitants generated throughout the study. Average amounts of waste (i.e., for the 6 waste types) in the intervention and the control groups for the first 2 weeks, week 5 and 6, and week 9 and 10 are shown in tables 9 and 10, presented in figure 27 for each waste type, and in figure 28 for edibles only (i.e., or once edibles). Paired t-test results are shown in table 11.

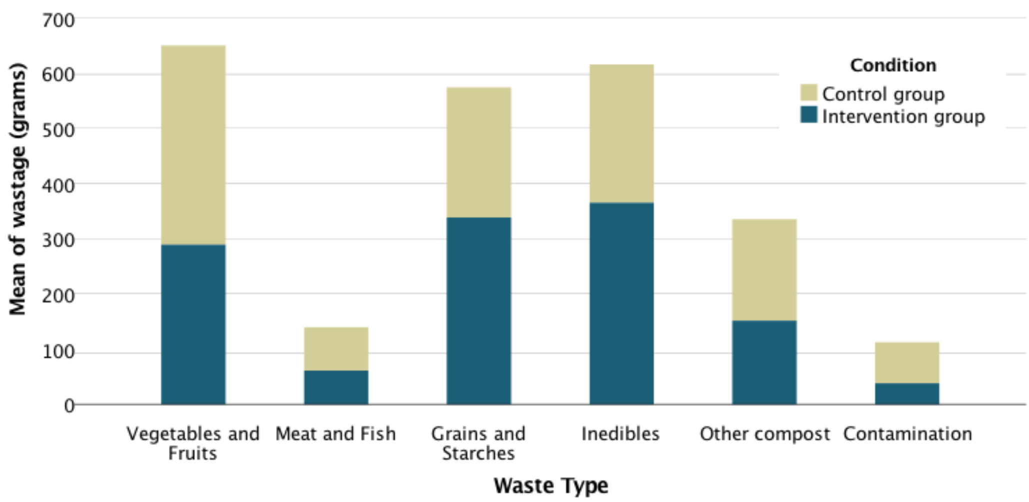

Figure 26.: The overall distribution of food waste types and amounts in grams.

Vegetables and fruits. No significant changes were found in the intervention and the control group between the baseline measure (M = 449.38, SD = 503.82 and M = 406.80, SD = 544.61, respectively) and the last 2 weeks of the study (M = 231.25, SD = 406.71 and M = 271.8, SD = 290.25, respectively) for the amount of wasted vegetables and fruits, $t(15)= 1.35$, $p = .197$ and $t(19)= .92$, $p = .367$. Although not significant, there was a larger decrease for the intervention group (from M = 449.38 to M = 231.25) than the control group (from M = 406.80 to M = 271.8). There were also no significant changes in the intervention and the control group between week 5 and 6 (M = 224.38, SD = 218.89 and M = 342.40, SD = 435.61, respectively) and the last 2 weeks of the study (M = 231.25, SD = 406.71 and M = 271.80, SD = 290.25, respectively) for the amount of wasted vegetables and fruits, $t(15)= -.06$, $p = .957$ and $t(19)= .65$, $p = .526$.

Meat and fish. No significant changes were found in the intervention and the control group between the baseline measure (M = 130.50, SD = 377.96 and M = 79.50, SD = 127.68, respectively) and the last 2 weeks of the study (M = 27.50, SD = 79.85 and M = 47.80, SD = 95.30, respectively) for the amount of wasted meat and fish, $t(15)= 1.07$, $p = .303$ and $t(19)= 1.20$, $p = .246$. Although not significant, there was a larger decrease for the intervention group (from M = 130.50 to M = 27.5) than the control group (from M = 79.50 to M = 47.80). Meat and fish are more expensive than other food types and contributes more to the total weight. Hence, these might have been incentives for saving them. Furthermore, no significant changes were found in the intervention and the control group between week 5 and 6 (M = 12.25, SD = 43.95 and M = 71.00, SD = 134.95, respectively) and the last 2 weeks of the study (M = 27.50, SD = 79.85 and M = 47.80, SD = 95.30, respectively) for the amount of wasted meat and fish, $t(15)= -.64$, $p = .531$ and $t(19)= .58$, $p = .567$.

Grains and starches. No significant changes were found in the intervention group between the baseline measure (M = 378.88, SD = 426.00) and the last 2 weeks of the study (M = 395.88, SD = 636.10) for the amount of wasted grains and starches, $t(15)= -.08$, $p = .939$. But significant changes were found in the control group between the baseline measure (M = 111.35, SD = 158.39) and the last 2 weeks of the study (M = 383.20, SD = 318.43), $t(19)= -3.46$, $p = .003$. The control group generated more waste for grains and starches by the end of the study. No significant changes were found in the intervention and the control group between week 5 and 6 (M = 272.75, SD = 315.01 and M = 247.70, SD = 352.72, respectively) and the last 2 weeks of the study (M = 395.88, SD = 636.10 and M = 383.20, SD = 318.43 respectively) for the amount of wasted grains and starches, $t(15)= -.70$, $p = .496$ and $t(19)= -1.55$, $p = .138$.

Inedibles. No significant changes were found in the intervention and the control group between the baseline measure (M = 320.13, SD = 544.71 and M = 273.10, SD = 330.63, respectively) and the last 2 weeks of the study (M = 478.63, SD = 661.59

Floornr	Group	Vegetables and fruits Baseline	Week 5-6	Week 9-10	Meat and fish Baseline	Week 5-6	Week 9-10	Grains and starches Baseline	Week 5-6	Week 9-10
1	I	1510	128	130	0	0	0	518	420	1142
2	I	20	0	62	0	0	0	80	438	1268
3	I	88	14	0	212	176	0	144	66	0
4	I	588	120	400	0	0	0	234	0	128
1	I	974	264	190	0	0	146	224	576	470
2	I	10	668	0	0	0	0	1324	292	0
3	I	176	292	52	0	0	0	0	16	0
4	I	80	82	86	14	0	0	346	10	0
1	I	234	398	110	58	0	0	1028	0	128
2	I	266	40	178	90	0	0	984	964	36
3	I	0	570	128	0	0	0	0	578	620
4	I	938	128	156	0	0	0	0	768	40
1	I	238	114	1714	190	0	294	380	180	262
2	I	1476	186	222	1524	0	0	758	56	14
3	I	332	580	110	0	0	0	0	0	2226
4	I	260	6	162	0	20	0	42	0	0
Mean		449.38	224.38	231.25	130.5	12.25	27.5	378.88	272.75	395.88
Std. Dev.		503.82	218.89	406.71	377.96	43.95	79.85	426.00	315.01	636.10
5	C	2210	554	76	244	0	0	202	438	1004
6	C	858	192	8	0	38	0	0	0	0
7	C	538	1180	0	38	0	0	410	150	0
8	C	882	566	540	0	0	0	12	494	432
9	C	138	592	32	0	0	0	24	192	20
5	C	226	502	70	0	0	0	0	452	432
6	C	0	0	42	0	0	26	0	0	166
7	C	94	14	100	0	0	0	0	78	0
8	C	164	1528	614	0	244	0	0	270	442
9	C	4	76	0	6	106	0	0	40	186
5	C	972	82	108	324	380	70	143	136	592
6	C	0	0	0	0	0	84	40	402	442
7	C	213	890	762	104	0	356	173	306	476
8	C	213	260	318	104	420	0	173	242	1012
9	C	934	90	234	194	0	66	422	30	526
5	C	472	20	600	438	0	254	484	98	20
6	C	0	274	116	0	0	0	0	0	124
7	C	72	16	392	138	232	0	144	1570	584
8	C	124	12	932	0	0	100	0	56	420
9	C	22	0	492	0	0	0	0	0	786
Mean		406.8	342.4	271.8	79.5	71	47.8	111.35	247.7	383.2
Std. Dev.		544.61	435.61	290.25	127.68	134.95	95.30	158.39	352.72	318.43

Table 9.: Summary of visual inspections for each food type at baseline measurement, week 5 and 6 (without social comparison information), and week 9 and10 (with social comparison information) for intervention (I) vs. control (C) groups.

Floornr	Group	Inedibles Baseline	Week 5-6	Week 9-10	Other compost Baseline	Week 5-6	Week 9-10	Contamination Baseline	Week 5-6	Week 9-10
1	I	0	532	2608	1082	282	484	6	0	18
2	I	18	12	364	18	50	16	0	18	0
3	I	0	390	550	228	146	74	270	186	0
4	I	0	176	234	130	48	166	18	6	42
1	I	296	1196	304	1156	152	166	0	14	12
2	I	32	148	110	150	0	18	24	732	0
3	I	252	180	302	92	116	12	74	6	0
4	I	388	164	246	62	24	24	0	0	142
1	I	2184	206	266	298	168	12	12	0	0
2	I	148	16	436	180	106	12	82	0	54
3	I	360	314	292	98	196	40	28	0	0
4	I	638	112	30	172	38	24	160	0	156
1	I	662	798	310	176	334	114	8	40	4
2	I	0	456	1494	12	90	10	0	2	6
3	I	0	110	26	152	194	84	0	0	82
4	I	144	516	86	54	58	0	12	60	0
Mean		320.13	332.88	478.63	253.75	125.13	78.5	43.38	66.5	32.25
Std. Dev.		544.71	314.31	661.59	346.25	93.90	121.15	74.24	183.57	51.50
5	C	456	8	0	652	308	244	220	6	654
6	C	140	148	68	200	56	32	18	4	0
7	C	148	208	236	146	268	56	52	0	0
8	C	12	520	458	32	218	202	0	0	0
9	C	0	82	8	122	176	38	34	38	0
5	C	22	104	202	60	146	68	66	4	18
6	C	218	40	62	270	0	128	94	84	12
7	C	16	298	74	142	146	0	76	42	20
8	C	96	368	288	68	420	232	0	8	80
9	C	78	428	12	168	128	178	0	30	0
5	C	208	314	510	108	152	304	258	326	554
6	C	116	4	54	42	76	182	0	128	0
7	C	902	176	230	3	56	270	170	216	338
8	C	902	384	240	3	242	1078	170	260	190
9	C	284	148	630	306	128	162	4	4	366
5	C	30	564	504	436	520	316	0	154	206
6	C	322	384	24	146	134	14	40	18	10
7	C	268	144	280	184	80	158	50	66	20
8	C	1142	438	358	158	190	276	0	54	6
9	C	102	32	398	128	46	40	0	0	16
Mean		273.1	239.6	231.8	168.7	174.5	198.9	62.6	72.1	124.5
Std. Dev.		330.63	176.53	194.50	154.98	128.69	230.65	80.02	96.13	199.92

Table 10.: Summary of visual inspections for non-food types at baseline measurement, week 5 and 6 (without social comparison information), and week 9 and10 (with social comparison information) for intervention (I) vs. control (C) groups.

and M = 231.80, SD = 194.49, respectively) for the amount of disposed inedibles, $t(15)= -.67$, $p = .513$ and $t(19)= .50$, $p = .624$. Also, no significant changes were found in the intervention and the control group between week 5 and 6 (M = 332.88, SD = 314.31 and M = 239.60, SD = 176.53, respectively) and the last 2 weeks of the study (M = 478.63, SD = 661.59 and M = 231.80, SD = 194.49, respectively) for the amount of generated compost, $t(15)= -.88$, $p = .395$ and $t(19)= .17$, $p = .870$.

Other compost. Significant changes were found in the intervention group between the baseline measure (M = 253.75, SD = 346.25) and the last 2 weeks of the study (M = 78.50, SD = 121.15) for the amount of generated compost, $t(15)= 2.66$, $p = .018$. But no significant changes were found in the control group between the baseline measure (M = 168.70, SD = 154.98) and the last 2 weeks of the study (M = 198.90, SD = 230.65), $t(19)= -.46$, $p = .652$. Marginally significant changes were found in the intervention group between week 5 and 6 (M = 125.13, SD = 93.90) and the last 2 weeks of the study (M = 78.50, SD = 121.15) for the amount of generated compost, $t(15)= 1.78$, $p = .096$. But again, no significant changes were found in the control group between week 5 and 6 (M = 174.50, SD = 128.70) and the last 2 weeks of the study (M = 198.90, SD = 230.65) for the amount of generated compost, $t(19)= -.48$, $p = .638$.

Contamination. Finally, no significant changes were found in the intervention group between the baseline measure (M = 43.38, SD = 74.24) and the last 2 weeks of the study (M = 32.25, SD = 51.50) for the amount of contamination, $t(15)= .53$, $p = .605$. However, marginal significant changes were found in the control group between the baseline measure (M = 62.60, SD = 80.02) and the last 2 weeks of the study (M = 124.50, SD = 199.92), $t(19)= -1.85$, $p = .080$. The intervention group showed a decrease in the amount of contamination, while the control group showed a marginally significant increase of contamination. Considering that students had finals in the last weeks of the study (hence, they might have been more busy), the residents in the control group seem to have paid less effort in sorting their trash than the residents in the intervention group. No significant changes were found in the intervention and the control group between week 5 and 6 (M = 66.50, SD = 183.57 and M = 72.10, SD = 96.13, respectively) and the last 2 weeks of the study (M = 32.25, SD = 51.50 and M = 124.50, SD = 199.92, respectively) for the amount of contamination, $t(15)= .68$, $p = .508$ and $t(19)= -1.31$, $p = .205$

Edibles. If all amounts are aggregated for only edible or once edible disposed foods and calculated per person per week with the assumption of 14 kitchen users per kitchen (See figure 28), there is a constant increase in the control group between the baseline measure (M = 298.82, SD = 354.86), week 5 and 6 (M = 330.55, SD = 306.80), and week 9 and 10 (M = 351.40, SD = 258.52). These changes, however, were not significant, $t(19) = -.32$, $p = .754$ and $t(19) = -.27$, $p = .792$, re-

Waste type	Comparisons	Intervention Mean	Std. Deviation	t value	df	Sig.	Control Mean	Std. Deviation	t value	df	Sig.
Vegetables and fruits	Baseline vs. Week 9-10	218.13	647.00	1.35	15	.197	135.00	653.46	.92	19	.367
	Week 5-6 vs. Week 9-10	-6.88	496.36	-.06	15	.957	70.60	488.75	.65	19	.526
Meat and fish	Baseline vs. Week 9-10	103.00	386.57	1.07	15	.303	31.70	118.49	1.20	19	.246
	Week 5-6 vs. Week 9-10	-15.25	95.01	-.64	15	.531	23.20	177.87	.58	19	.567
Grains and starches	Baseline vs. Week 9-10	-17.00	871.03	-.08	15	.939	-271.85	351.09	-3.46	19	.003**
	Week 5-6 vs. Week 9-10	-123.13	705.13	-.70	15	.496	-135.50	391.71	-1.55	19	.138
Inedibles	Baseline vs. Week 9-10	-158.50	945.21	-.67	15	.513	41.30	370.46	.50	19	.624
	Week 5-6 vs. Week 9-10	-145.75	665.14	-.88	15	.395	7.80	210.76	.17	19	.870
Other compost	Baseline vs. Week 9-10	175.25	263.72	2.66	15	.018*	-30.20	294.49	-.46	19	.652
	Week 5-6 vs. Week 9-10	46.63	105.07	1.78	15	.096	-24.40	228.08	-.48	19	.638
Contamination	Baseline vs. Week 9-10	11.13	84.32	.53	15	.605	-61.90	149.79	-1.85	19	.080
	Week 5-6 vs. Week 9-10	34.25	34.25	.68	15	.508	-52.40	178.45	-1.31	19	.205
Only edibles	Baseline vs. Week 5-6	224.79	500.92	1.79	15	.093	-31.73	446.27	-.32	19	.754
	Week 5-6 vs. Week 9-10	-72.63	418.51	-.69	15	.498	-20.85	349.17	-.27	19	.792

*Significant group difference; * $p < .05$, ** $p < .01$.*

Table 11.: Paired t-test results summary for each waste type and condition comparing the average weight at baseline with the average weight at week 9 and 10, and the average weight at week 5 and 6 with the average weight at week 9 and 10. Only edibles contains vegetables and fruits, meat and fish, and grains and starches.

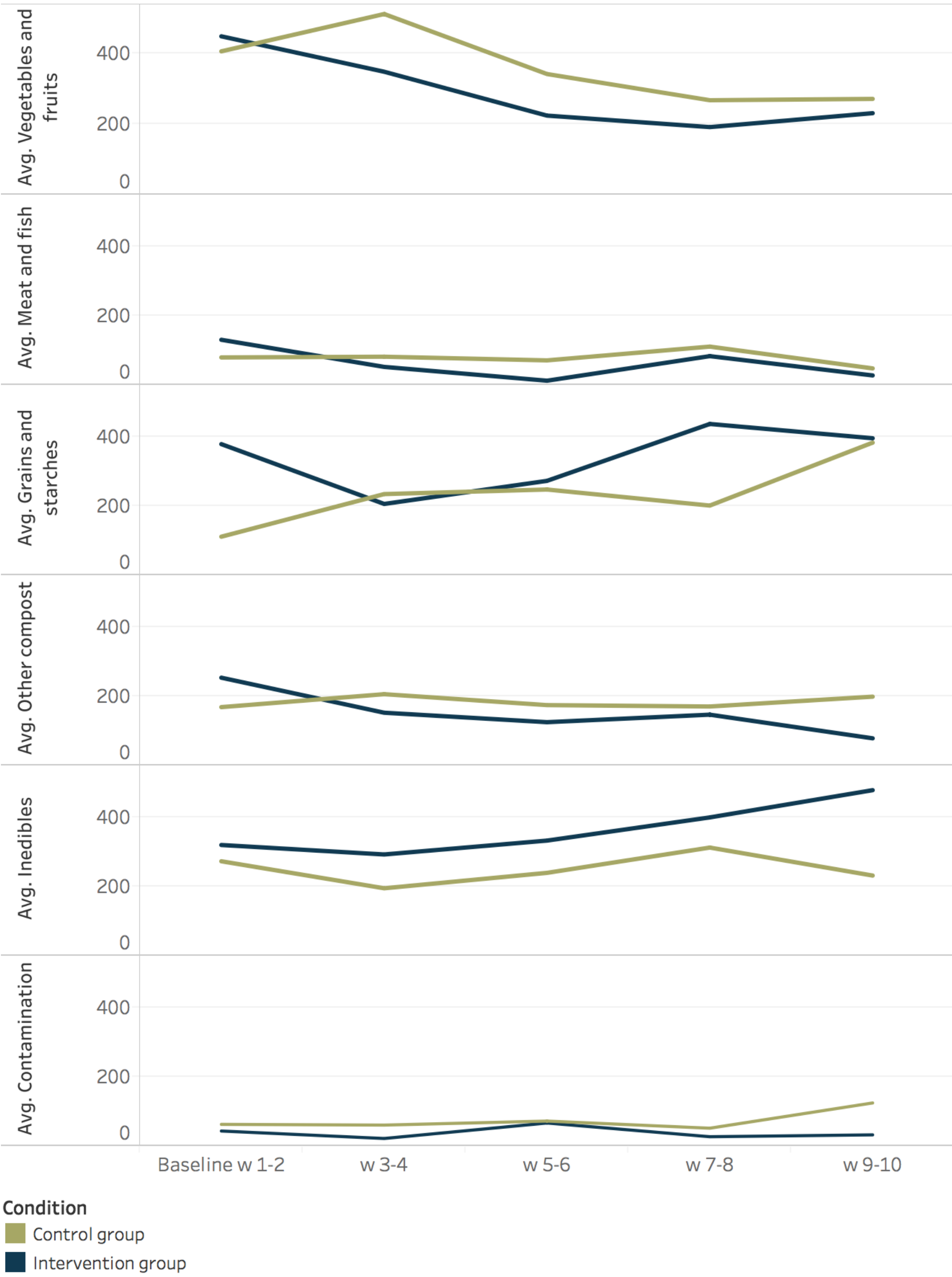

Figure 27.: Average amounts (in grams) of food waste type generated by the control group vs. intervention presented per 2 weeks. *Week: (w).

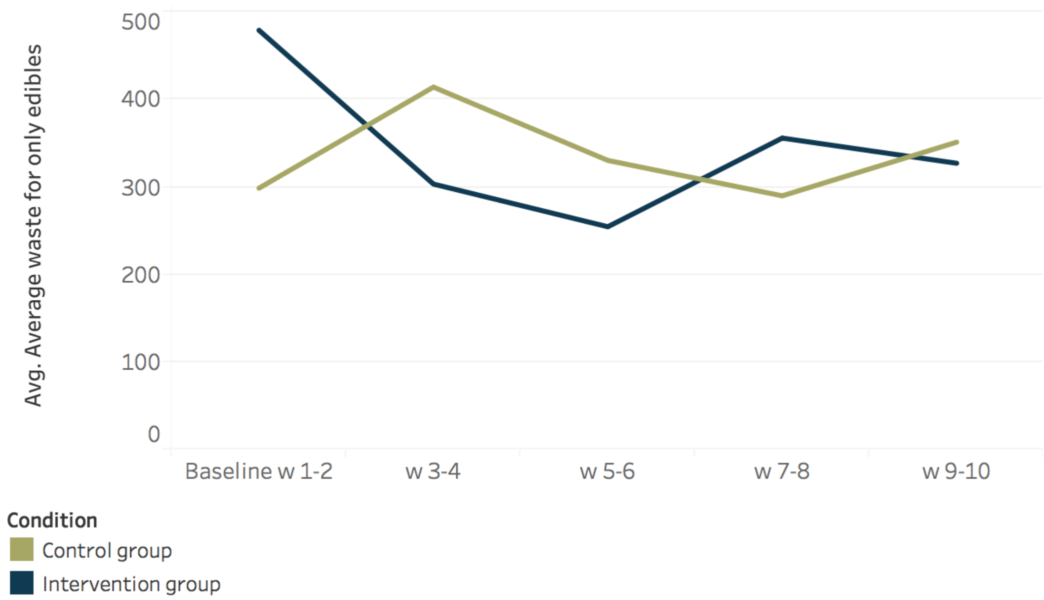

Figure 28.: Average amounts (in grams) of only edible or previously edible wasted items generated by the control group vs. intervention presented per 2 weeks. *Week: (w).

spectively. In the intervention group there was a prominent decrease from the baseline (M = 479.38, SD = 467.66) to week 5 and 6 (M = 254.69, SD = 178.91) and then increased again in week 9 and 10 (M = 327.31, SD = 384.29). The decrease in the first month was marginally significant, t(15) = 1.79, p = .093, and the increase in the second month was not significant, (15) = -.69, p = .498. All collected data for each individual inspection is included in Appendix E.

In sum, E-COmate might have had impacts on food waste patterns such as for grains and starches, other compost such as paper towels, and contamination. E-Comate might further impact edibles in general, but only when there is no negative social comparison information. In validating these findings, further research was done on *how* these waste patterns might have been impacted. This information was required through inhabitants reflections on the role of E-COmate in their everyday lives and their engagement with the technology during the interviews. Findings are triangulated with the waste patterns discussed above and E-COmate's design aspects.

The role of E-COmate in raising awareness

In this section, only those items and categories are included and discussed for which raters came into substantial agreement (i.e., kappa is 0.61 - 0.80). First, the constant presence and immediacy of E-COmate served as a reminder for inhabitants:

"Every time I was in there I sort of glanced at it." - Eva

"I can't remember any day I entered the kitchen and I never looked at it. The setup and the place it is in a convenient place, that is almost the second or first thing to see when you are in there." - Isaac

The way E-COmate was set up helped in raising awareness and triggered instances for reflection: this was found mainly at the time of disposal. Participants reported doing final checks to see if they were using the right compartment or if the item really needed to go. Examples of comments related to these moments of reflections were:

"I feel a little self-conscious when I throw something away, cause I see.. I know its recording when I throw something away its like Oeh... So its a little... its making me double check when I am throwing out anything.." - Eva

"I was a little more hesitant to what I put in there. I double checked what I put in there to make sure." - Farrah

"An example from this morning.. I usually don't throw food in general.... I have a bunch of grapes and two are like totally rotten and I throw them and today I was thinking, oh interesting because in my head I don't waste food, because i just hate the idea of wasting food but there are 2 rotten fruits and I am throwing them and that in a way is food waste." - Geraldine

These findings could explain the decreased amount of contamination in the intervention group by the end of the study, and the marginally significant increasing amount of contamination in the control group towards the end of the study. At the end of the study inhabitants had final exams, which might have been a reason for the control group to care less about separating plastics or other contaminations from organics or food waste items, while the intervention group were more motivated to double check at the time of disposal.

Overall, participants agreed that E-COmate raised self-awareness as well as collective awareness of waste amounts generated on a daily basis. Participants reported that they usually do not actively reflect on food waste-related behaviors and nor was it something they think about. With the deployment of E-COmate, food waste became more visible to them and easier to reflect on. This gave them something to improve from and a direction for action. Some examples of answers that indicates self-awareness were:

"It gives us a baseline and lets us know what we are doing currently so that we have somewhere to improve from." - Alysa

"I didn't think about it before but this puts a number on it. It gets it more thinkable, a little easier for me to think about it." - Farrah

"I never knew I was wasting anything . . . So that type of discovery itself is one push to someone doing something about it. So thats a great thing."- Isaac

E-COmate was also found to provide visibility of the collective impact of a community:

"It put stuff in perspective. Because its easier to think: oh I waste this much food. But now I am seeing how much this one kitchen waste and then you think that adding on to other floors and it starts really adding up." - Eva

Although, these examples above show an increase of awareness, a couple of participants were already aware. Instead, E-COmate confirmed their thoughts on the issue and improved their understanding in actual wasted amounts:

"Just judging from what I would see in the compost bin I thought I already had an expectation on how much food waste there is. It seems that people are throwing quite a bit away, especially when they got pizza or whatever then that would be in the bin. And I thought oh thats a lot. And having the amount on the prototype help too for my understanding of how much is actually being thrown away that day." - Hannah

"I never think..I just had a glimpse idea. Before the system came I just look at how the bin is full and I am like ...mmm..., and think that people are wasting a lot. I am wasting a lot. But with the right information, I am able to actually say: AH! see! This is what we are wasting. Surprised no, but my conviction of change was straight then. It was like, ok yeah... this makes sense and now we have to do something."- Isaac

Hence, individual and collective awareness, specifically at the time of disposal, might have had impacts on the overall decreasing amount of wasted edibles and contamination in the intervention group. E-COmate also helped them in understanding the amount of food waste generated by their group by putting a number to it. In the next section, findings are presented on how awareness, caused by the immediacy of E-COmate, further resulted in instances where participants took actual actions in reducing waste.

E-COmate and active engagements

Again only those items or categories are included and discussed for which raters came into substantial agreement (i.e., kappa is 0.61 - 0.80). As a first example, participants reported to feel more motivated in sorting out the garbage or plastics from the organics explaining the decreased amount of contamination in the intervention group by the end of the study, and the marginally significant increasing amount of contamination in the control group towards the end of the study:

"I like that it encourages me to use that instead of the garbage bin. If I come in with a bag of food or a bag of trash with food, with that thing I would make an effort to separate my food waste." - Cathy

"Definitely, I am more aware of how much I actually put into the bin now. I try to minimize how much goes in as opposed to.." - Alysa

Interestingly, more examples were provided on instances around planning and buying food in the grocery stores. Participants reported to be more considerate about their food-related choices in relation to shopping and doing groceries. They provided specific examples of solutions on how they tried to reduce food waste:

"I actually bought less food this weekend. I was shocked when i looked at the amount. I usually spend at least 60 or something in total for everything I am buying for during the week. I ended up spending 50, I was really shocked. The lady at the checkout was like oh you are spending cheaper now, I was like really?" - Derrick

"Maybe I have thought for example like carrots. I usually don't use the tops. And you could use it for pesto and stuff. I have though like I don't want to through out so I just buy carrots that does not have them you know. Maybe in that way it has influence." - Geraldine

"It impacts the way I buy things. It doesn't hurt to walk often to the market. For example I eat vegetables, I am vegan. I eat a lot of fresh food. So instead of keeping them in my fridge when it stays there sometimes i might not like it or gone by the things i need and eat them. It made me walk to nesters a lot. I thought it was worth it than wasting a lot of foods." - Isaac

"Specifically as far as food waste goes, I think when I am cooking I am very aware but when I am shopping its more like avoiding buying things in packages, I guess. So that I reduce my amount of garbage that I produce." - Alysa

This last example could also have accounted for the decreased amounts of contamination (whereas in the control group contamination amounts were increasing). And overall, these examples could have accounted for the decreased amounts of wasted edibles in the intervention group between the baseline and week 5 and 6. Interestingly, participants did not provide examples of intentions of preventing the waste of grains and starches. This is in accordance to findings from the visual inspections data where the amount of wasted grains and starches only decreased in week 3 and 4 right after the baseline measure and increased right afterwards towards the end of the study. Perhaps, this is due to the fact that wasted grains and starches were mainly cooked items such as rice and pasta, or bakery products: participants reported no impacts on cooking practices. Despite the high amounts of wasted grains and starches observed in the visual inspections, participants did not acknowledge it as a common food waste type in the questionnaire by both the intervention and the control group.

With regard to social engagements, there were only some instances which was less than expected. For example, two participants shared more food with each other as they regularly meet in the kitchen. Hence, the group feedback provided in a public space such as a shared kitchen gave them a topic to talk about:

"I see it all the time. Especially if there is someone we always like check and see how much is it." - Bo

"It encourages me to offer or to share food more. I know Farrah and we talked before about food waste and food in general. We have the same mind on that. Sure, it gives us something to talk about." - Hanna

These social interactions are expected to impact actions towards reducing food waste indirectly through social surveillance or norm activation. Furthermore, the social design aspects of E-COmate (i.e., by providing group feedback as well as the use of negative social comparison information), seem to impact motivation in reducing waste. For example, edibles were decreased when social comparison information was not displayed, while it increased in the second half of the study when negative social comparison information was displayed (See figure 28). Hence, group feedback influences food waste positively but if social comparison is negative in nature it impacts negatively. However, other compost such as paper towels continued reducing (See figure 27), probably because it requires less effort than reducing food waste.

The link between social comparison information and the level of motivation is further confirmed by the findings on technological engagement. Figure 29 presents the number of likes and dislikes inhabitants shared through the interface of E-COmate. Overall, the graph shows that there is no clear increase or decrease of the total number of likes and dislikes when the display showed no social comparison information ($M = .51$, $SD = .99$) vs. when social comparison information was present ($M = .44$, $SD = 1.01$), $t(99) = .54$, $p = 593$, reflecting a continuous engagement. However, the number of likes vs. dislikes was significantly different when social comparison information was not present, $t(123) = -4.608$, $p = .000$. Without social comparison information, users pressed the like button more often (M =

.40, SD =.81) than the dislike button (M= .10, SD =.37). When social comparison information was present, the number of likes (M = .27, SD = .69) vs. dislikes (M = .17, SD = .49) was not significantly different, t(99) = -1.517, p = .132. Hence the number of dislikes did not significantly change, RSquare = 0.018, p = 0.323, while the number of likes did significantly change, RSquare = 0.079, p = 0.036. These findings show the relevance of including social comparison information, and how negative feedback can reduce motivation in taking actions towards reducing food waste.

Finally, active engagements depend on the attitude of users towards E-COmate. Although it impacted awareness and encouraged users in translating reflections towards actions, this was not always the case for all participants. Some participants mentioned the difficulty of trusting in either the accuracy of the prototypes or the eligibility of other users in using the Zero Waste station as it is supposed to. The use of servings and averages, for example, did not entail sufficient information for the users as it left questions open such as *what* is wasted, *when* it was wasted, and *who* wasted. Some participants were convinced that paper towels contributed most to the overall weight, which was not the case according to visual inspections. Their conviction is reflected in the significantly decreased amount of paper towels by the end of the study. Participants also reported that they do not feel responsible for what is being visualized. The following examples shows comments from those who were encouraged:

"I like that it encourages me to use that instead of the garbage bin." - Cathy

"Surprised no, but my conviction of change was straight then. It was like ok yeah this makes sense and hm now we have to do something." - Isaac

And those who were not:

"I am still questioning to what level it is accurate. Does it really show how much food waste we are producing?" - Geraldine

"It doesn't differentiate what is food and what is not food, like paper towels." - Bo

"There is a dispersion of responsibility if it comes to big groups. I have no idea what the other people on these floors are doing." - Farrah

These opposed thoughts were mentioned because the display was not specific enough resulting in a dispersion of responsibility or uncertainty.

In sum, E-COmate triggered instances of reflections, especially at the time of disposal, engaging users in waste separation and decreasing the amounts of contamination. E-COmate also influenced the way participants do groceries decreas-

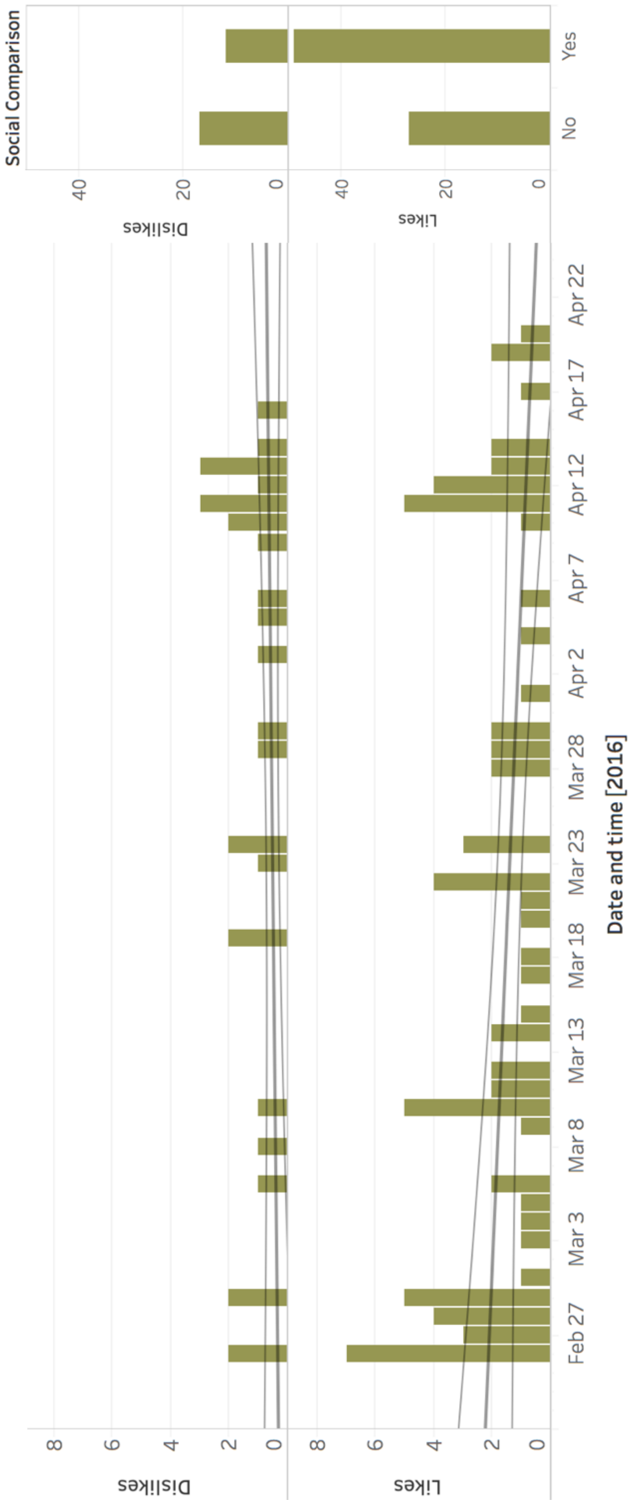

Figure 29.: Technological engagement: number of button presses over time.

ing the amounts of wasted edibles found during the inspections. Furthermore, findings showed the impact of including social comparison information, specifically how negative feedback reduced motivation in taking actions against food waste. The main Issues with E-COmate were on its accuracy and the diversion of responsibility, which prevented some users in feeling responsible towards the generated waste or in trusting E-COmate.

5.2.3 Discussion

Based on these findings, design implications are presented here that could serve as a basis for understanding basic requirements for effective eco-feedback design within the context of food waste. The findings on E-COmate and its impact on food waste, awareness, and engagements can be organized into three categorical themes: (1) interactivity: constant reminding and responsiveness, (2) accuracy and specificity, and (3) persuasive strategies to motivate users. The design implications discussed within these themes were either explicitly suggested or can be inferred from comments. Only those items are included and discussed for which raters came into substantial agreement (i.e., kappa is 0.61 - 0.80).

Design Implications

Interactivity: constant reminding and responsiveness. As discussed in earlier chapters, food-related behaviors often occur without mind. Having technology like E-COmate embedded in consumers environment that can help them in remembering their food waste-related behaviors help raise awareness, improve understanding around the issue of food waste, how this relates to individuals' behavior, and encourage active engagements. E-COmate have shown to provide a constant reminder at the moment of disposing and even had impacts on decision-making at the grocery store. This supports previous research claiming that persuasive technology can greatly contribute to the design of motivational interventions (Midden et al., 2008), but further extends the application field to food waste-related behaviors. However, the design could be improved by making it more responsive. For example, the data visualization could be updated as soon someone disposes an item so that feedback is immediate and the personal contribution more visible. Another example could be to provide consumers feedback on a mobile phone when they are doing groceries, which could include tips (related to a recent waste activity) that help them to shop more consciously as a way to prevent food waste. Some examples of indicators for interactivity are:

"It should be something that is a constant reminder to everyone." - Isaac

"People may not look at it all the time unless its right there as they are doing something. Its also on this wall and generally people look at the sink or just not looking at the wall."

- Hannah

Opposed to preferences for weekly averages for other types of consumption, such as for water usage (Froehlich et al., 2012), food waste awareness seem to require a more immediate feedback (i.e., for each wasteful behavior/each day). This could be explained by the variability of food waste behavior, for example in terms of reasons for the wasteful behavior or the context in which it occur.

Accuracy and specificity. Participants reported liking the quantification of food waste, but also showed concerns about the level in which it was accurate. Many participants were assigning most of the weight to either inedibles or paper towels, even though edibles were wasted more as found in the visual inspections. Providing specific details on how the potential food waste amounts is calculated and the composition of the waste content (e.g., edibles vs. inedibles) would be necessary to gain consumers trust in the data visualization to enhance effectiveness. It might also be useful to provide personalized data, for example, by showing immediate feedback at the time of disposal so that users can see their own impact. Some examples of indicators for accuracy and specificity are:

"Mostly the fact that I am still questioning to what level it is accurate." - Geraldine

"It needs to be more specific. Even if you see you are wasting stuff, first it is... Oh I am wasting this thing but then its actually a lot of paper." - Bo

The main challenge here is the ability to reliably measure and present food waste, which is different for water and energy consumption. There are different food waste types, different type of consumers, and costs, which further depends on location and type of store/market. This complexity, makes it more difficult to find a metaphor that is evenly perceived by all consumers. Therefore, although metaphors are commonly used in previous eco-feedback research (Froehlich et al., 2012; Froehlich et al., 2009) to help understanding, this might not be the case for visualizing food waste.

Combine persuasive strategies as motivators. Participants acknowledged the usefulness of strategies such as self-comparison so that there is a better understanding of the necessity in taking action. Also, the relevance of social comparison (green competition) has been acknowledged by participants:

"Its motivating in that sense that you want to have the best score I guess compared to other floors." - Farrah

This relevance is further reflected in their waste patterns when negative feedback was provided. Eco-feedback without social comparison information had a positive impact on the amount of edibles being wasted, whereas eco-feedback with negative social comparison information had negative impacts. Hence, although social comparison was favorable, the visual inspections data showed a decrease in once edible or still edible food waste in the first month when social comparison was absence and an increase in the second month when social comparison was present. This increase could be explained because of the finals at the end of the study or because of the type of feedback that was given (i.e., mostly negative), which might have further reduced their motivation to prevent waste. Based on these findings, in case of negative feedback, technology could include tips or suggestions for actions to keep consumers motivated and involved. Designing for action has been suggested by Maitland et al. (2009), which will be further discussed in *Chapter 7*. However, rather than just focusing on providing a solution, and as eco-feedback has shown to impact active engagements (e.g., participants were able to come up with solutions), these strategies (i.e., self-comparison, social comparison and feed forward information) should be combined: consumers vary in concerns, interests, and values. By providing a combination of these strategies, consumers could choose how to identify with the information, and to which extend it can support them in the contexts of their own everyday lives.

Limitations

This study contains several limitations. The first is with regard to the simplicity of the display. More complex displays with more information should be evaluated and deployed. For example, only negative social comparison feedback was provided and was not compared with positive social comparison feedback: both positive and negative information should be evaluated in a deployment. In the next chapter, more detailed versions of displays are first evaluated retrospectively. This will, however, require a longer study. Furthermore, the current prototype cannot distinguish different food types, making it more difficult to define a serving more accurately (e.g., 200 grams of fruits might be one serving whereas 200 grams of meat could be 2 servings). Future developments in sensor technology or image recognition is expected to be able to resolve this issue. Finally, statistical analysis alone is insufficient for meaningful interpretations with small sample sizes. However, in this study the qualitative findings were used to support the quantitative data.

5.3 CONCLUSION

The aim of the study was to gain an understanding to what level eco-feedback applied to food waste could impact awareness and encourage active engagements in trying to reduce food waste. Although previous work have pointed out that not providing an explicit solution to the user is a limitation of eco-feedback (Brynjarsdttir et al. 2012; Maitland et al. 2009), this study showed that E-COmate had impacts on awareness as well as engagements towards reducing waste. Participants found their own ways on how to reduce food waste and E-COmate provided a starting point and motivation to act. However, there are some design implications. The first is on presence and interactivity. Eco-feedback is advantageous in raising awareness in two ways. First, information is provided within a setting relevant for the targeted behavior and is more personalized (i.e., opposed to more common strategies like campaigns). Second, with current lifestyles where food behaviors are habitual or unconscious (i.e., making consumers less aware), technologies that does not require manual or user-initiated tracking of the waste (e.g., such as with diaries or with the use of multimedia to gather information) is expected to have more impact. With E-COmate the intention was to create a more constant perceptual connection (Strengers, 2011) towards the waste and presence of the issue pervasively as well as with the choices that led to wasting so users can reflect on those. It could further help remind users during their every day activities (e.g., during cooking) at a daily basis. This every day aspect might be necessary as intentions can disappear quickly amidst other activities. Indeed, findings in this study showed that E-COmate helped in reminding users. Participants also required accuracy and specificity. Findings showed that participants were not aware whatsoever or had only a slight idea of what is being wasted. E-COmate helped in clarifying this more explicitly. Quantifying and visualizing food waste amounts helped in enhancing awareness and understanding of the issue of food waste. It was considered a starting point for action, but more accuracy and specificity was needed. Finally, green competition was a motivating factor but only when the information was positive. As eco-feedback has shown to negatively impact active engagements when social comparison was negative in nature, it should be combined with feed forward information such as actionable suggestions. This is further discussed in *Chapter 7*. Overall, all these findings and design implications were supported and validated with actual observed food waste patterns, where those who were using E-COmate showed decreases in edible food waste and contamination. In the next chapter, a set of more detailed display visualizations are evaluated to further discuss design implications.

6 DISPLAY DESIGN

As part of the interview discussed in *Chapter 5*, participants were presented with additional and more detailed display visualizations to gain insights in their preferences in the level of detail and social scope of feedback information. Taking personal and situational considerations, as well as the complexity involved in food-related behaviors, different display dimensions were presented and discussed retrospectively to understand their limitations and considerations. The display design dimensions that were explored showed differences in *data granularity*, *time granularity*, *measurement unit*, *comparison information*, and level of *self-control*. For each dimension, participants were asked which display they find more motivating and *why*. These findings also provided information on further design implications for E-COmate and eco-feedback applied to food waste in general.

6.1 DISPLAY DESIGN DIMENSIONS

Future technology is expected to be able to capture domestic food waste unobtrusively. Emerging possibilities of smart kitchen appliances is expected to be able to calculate and visualize food waste data at the right time and at the right moment so it can positively impact our food-related decisions. Although capturing this data can be technologically challenging, this chapter first explores how the visualization can be done effectively. In order to do this, a set of more detailed visualizations were designed with isolated eco-feedback design dimensions as introduced by Froehlich et al. (2012) who applied these design dimensions for domestic water usage. The visualizations were not deployed and were only presented at the end of the deployment. The visualizations were designed with three design dimensions to explore preferences in the level of detail: *data granularity*, *time granularity*, and *measurement unit*. Two additional dimensions were evaluated with the aim at exploring influence mechanisms with differences in the social scope of information: *comparison information* and *self-control*. Although

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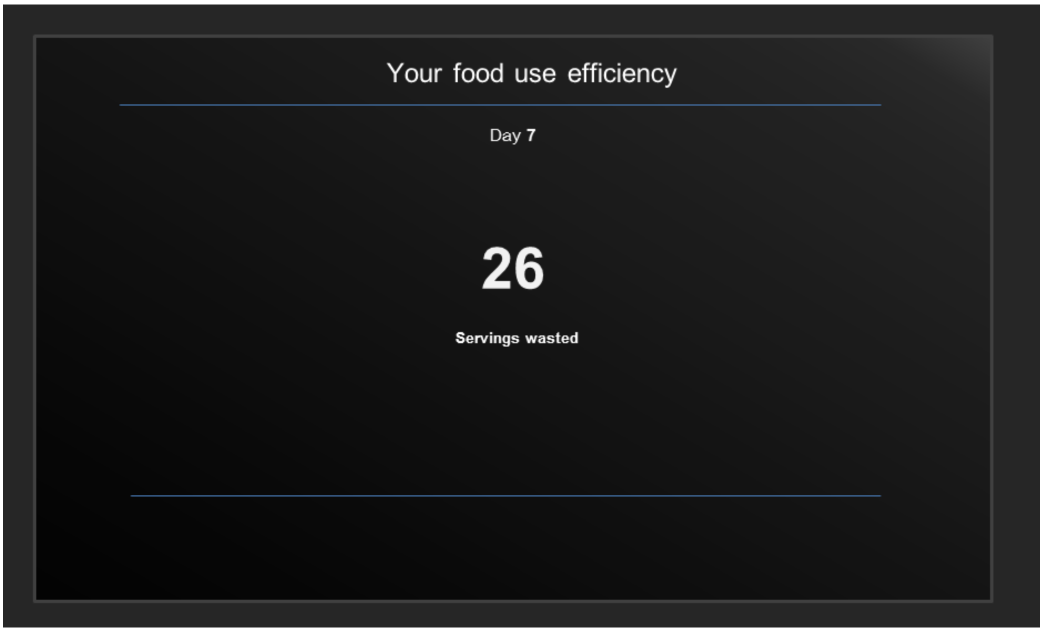

Figure 30.: Data granularity; display 1 shows the total servings wasted so far.

these dimensions are discussed separately, they could be each others counterparts and used in combination. The reasoning for exploring users preferences in these dimensions is to better understand differences in design requirements for visualizing food waste vs. other types of consumption such as water or energy. Next, each design dimension is explained as well as its importance for inclusion in this evaluation.

6.1.1 Data granularity

Data granularity refers to the level to which data is sub-divided. Two displays were designed: one with only the total number of servings wasted so far (See figure 30) and one with the distribution of the different types of food waste (See figure 31). This design dimension is included because different types of food waste might be related to different reasons. For example, the findings described in *Chapter 2* showed the disposal of grains depended on how participants were dealing with leftovers, while vegetables were mainly disposed because it went bad or were doubtful which was further caused by overbuying or forgetting. Knowing details on the type of food waste is expected to provide consumers with more actionable information. Moreover, from an environmental perspective, different food types impacts the environment differently. For example, meat requires more land and water than vegetables and fruits and is relatively more expensive. Hence, different food waste types might be reflected on differently.

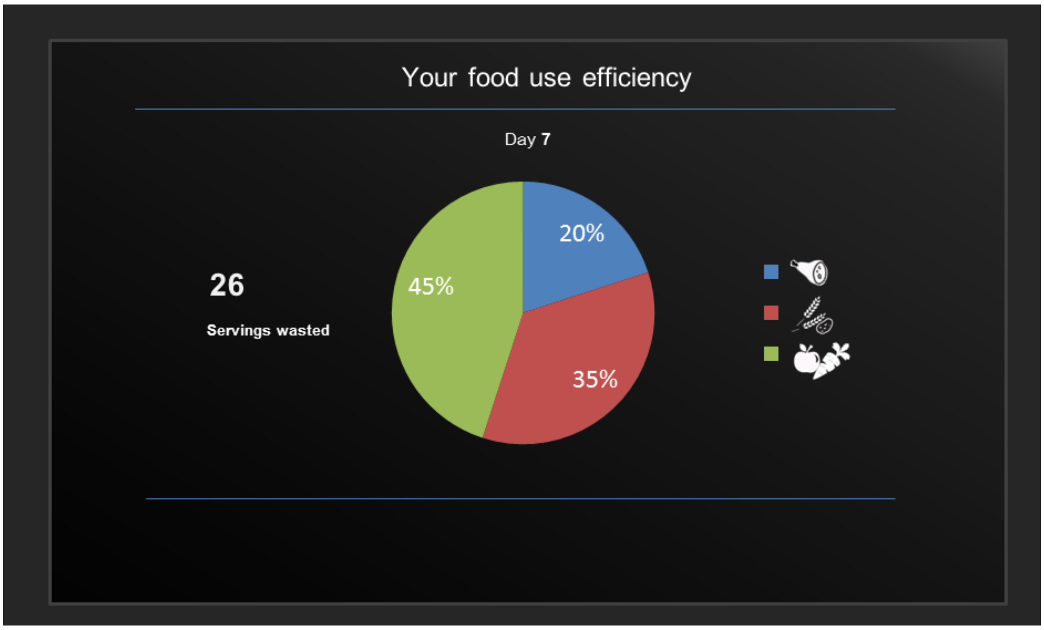

Figure 31.: Data granularity; display 2 shows the total amount distributed for different food types.

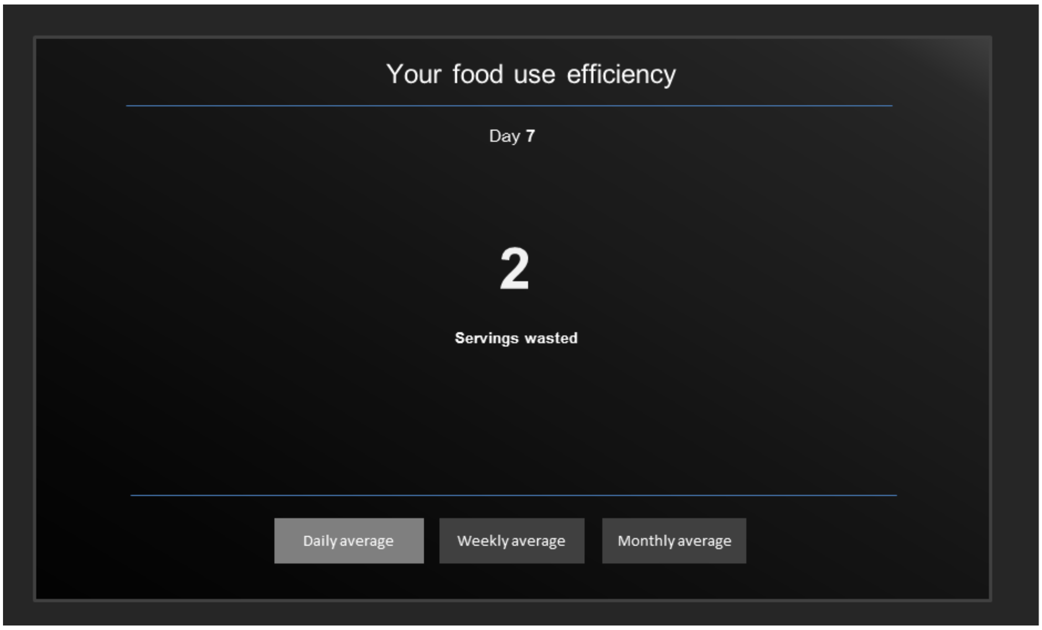

Figure 32.: Time granularity; display 1 shows the average weights with the possibility to switch between daily, weekly and monthly averages.

Figure 33.: Time granularity; display 2 shows daily amounts for the past week with the possibility to switch to an overview of the past month or the past year.

6.1.2 Time granularity

Time granularity refers to the temporal window in which food waste data is calculated and visualized. For this dimension, two displays were designed: one showed average weights of food waste with the possibility to switch between daily, weekly and monthly averages (See figure 32) and one display in which daily amounts were shown with the possibility to switch between the past week, the past month or the past year (See figure 33). Although for water usage, weekly averages were preferred (Froehlich et al., 2012), in the context of food waste daily details might be preferred because of the variability of food waste behaviors. With the second display, consumers could learn from every single instance where lots of waste occurred and reflect back to that specific instance. They could also look for patterns, changes and improvements. The objective in evaluating this dimension is to explore users preference or interest in either having insights in average amounts or the ability to see how waste patterns change over time.

6.1.3 Unit of measurement

The unit of measurement refers to a quantity used to measure and present, in this case, food waste amounts. These amounts could be expressed in weights or in metaphors. Eco-feedback researchers commonly use metaphors to enhance understanding: some examples are the number of jugs and oil trucks for water

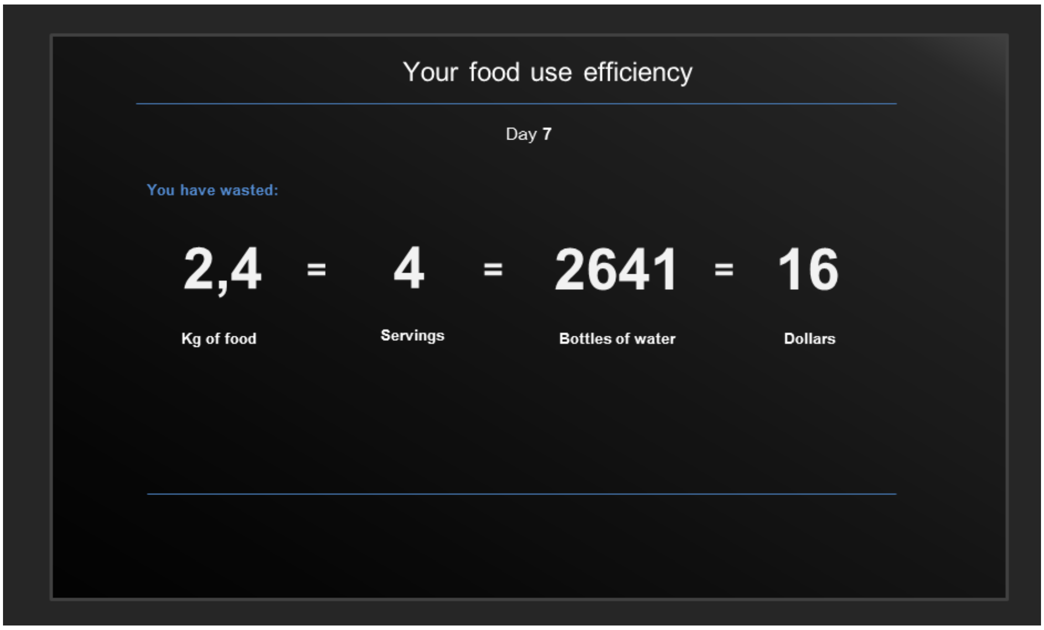

Figure 34.: Measurement unit. This display shows four different types of measurement units.

usage (Froehlich et al., 2012) and the number of water bottles saved when a dispenser is used at Intel labs instead of liters or gallons (See *Chapter 4* for more examples on metaphors). To explore consumers preferences in the type of measurement unit for food waste amounts, a display was designed in which the amount was expressed in weight, in servings, in costs and in terms of water usage for the production of the wasted foods (See figure 34). With weight, consumers could reflect on a specific measure which they could interpret freely (e.g., what it means in terms of servings, meals, days of food, or costs). Servings as a food-related measure was expected to be easier to understand reflecting a free meal. Cost was included because economic motivations has been used often in electricity and water feedback research according to a meta-study (Ehrhardt-Martinez, Donnelly, and John, 2010). Although, it was found to have minor impacts (Delmas et al, 2013), food is more expensive than water or electricity, which might catch consumers' interest in knowing the costs related to food waste. Another reason for including costs is because food-related decisions are often based on economic motives. Finally, water usage for the wasted food amounts were included because of the environmental aspect attached to it and the larger number it would show, which is expected to have raise awareness on the global issue. These different measurement units were presented to participants to trigger conversation and to uncover aspects underlying these units that makes it understandable and motivating to reduce food waste.

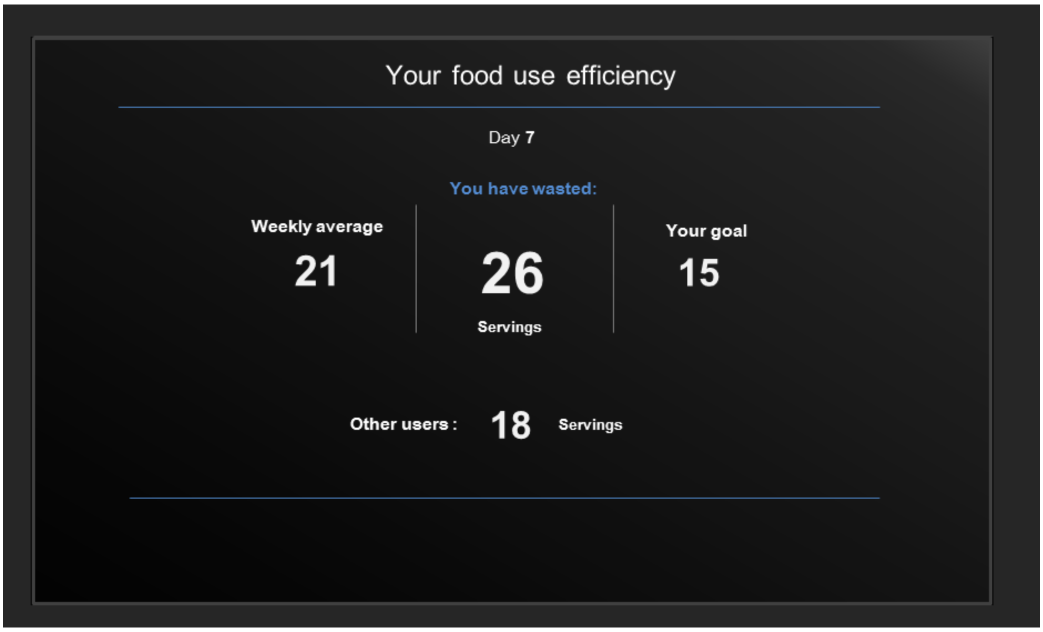

Figure 35.: Comparison information. This display shows comparison information with self comparison, goal comparison and social comparison.

6.1.4 Comparison information

Comparison is a strategy commonly used in current feedback display designs to show usage relatively to a norm. For evaluating participants preferences in comparison information, one display was designed like the display that was deployed. This display included three types of comparison: self comparison, goal comparison and social comparison (See figure 35). For self comparison, a weekly average of wasted servings was presented next to the total amount so far. Goal comparison was included to trigger conversation on consumers' interest in setting a groups goal versus an individual's goal. Goal setting was found to significantly impact the average amount of energy use, and hence, is important to consider (McCalley, de Vries,and Midden, 2011). Finally, social comparison was included because we often compare ourselves to other people to find out how we are doing when objective measures for self-evaluation are missing (Festinger, 1954). In current eco-feedback research, social comparison is a common influence strategy to motivate reducing consumption and seem to be successful when facilitated through technology (Midden and Ham, 2013; Foster and Lawson, 2013; Odom et al., 2008). Overall, the objective is to explore which comparison information consumers find more motivating: whether they are more willing to improve themselves or rather value their performance in comparison to others.

6.1.5 Self-control

Food-related behaviors happen mostly at unconscious levels with decisions being made without much thought. Persuasive and pervasive technology could aid by providing real-time information on the background that catches consumers attention and hopefully impacts behavior. So far, the deployed prototype and display dimensions presented above allows for self-control as information is visualized and can be reflected upon on a voluntary basis. Self-control is used to refer to conscientiousness and self-regulation of the self (Moffitt et al., 2011). The design, however, could aim at being more directive by increasing the level of persuasion. Therefore, participants were asked to discuss their preferences with regard to two displays: the deployed display visualization vs. one that is more interactive as shown in figure 36. This second display has four compartments for different food types integrated in the bin. Each compartment has an opening system that slides open when motion is detected. But each compartment opened and closed with different speeds depending on the frequency of usage. For example, when waste is disposed more often in one compartment than in the other compartments, it would opened slower and close faster than other compartments. The objective

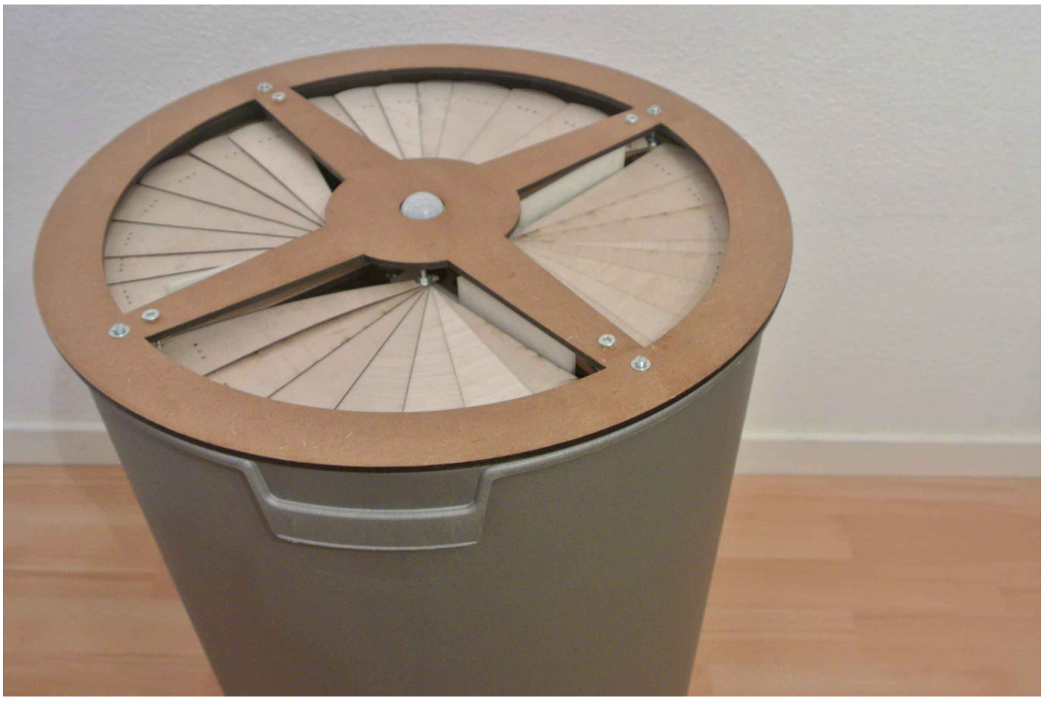

Figure 36.: This interactive and adaptive bin was designed in a Master thesis by Marieke Acquoij (Acquoij, 2015). It contains 4 compartments which open up with different speeds depending on how often they have been used.

is to explore preferences for the level of self-control as well as responsiveness in food-waste related eco-feedback technology.

6.2 INTERVIEW STUDY

To evaluate the display dimensions, interview participants from the deployment study described in *Chapter 5*, were presented with the display design dimensions on a laptop during the second part of the interview. For each dimension, participants were asked retrospectively which display they find more useful in motivating them to prevent food waste and *why* (open ended).

6.2.1 Methodology

Insights were based on reactions informed by real long-term use of E-COmate. Although, reported motivations may not directly translate to reduced consumption, their reactions can be supported with actual observed behaviors from the deployment.

6.2.2 Findings

Data granularity

Almost all interviewed participants saw the value in knowing which types of waste they generate and how this was distributed. Information on which food type they commonly dispose was expected to be more actionable: it could provide them with a more specific goal to aim for. Additionally, participants would have liked to see the amount of inedibles relative to actual food waste. Without this information, participants might try to justify food waste amounts to inedibles as a major contribution. Some examples of comments supporting the visualization of different food waste amounts are:

"You have more of a specific goal so its more containable." - Alysa

"When its broken down to what exactly has been wasted is very good. I think you would go into a deeper reflection and you would try to figure out how you waste so much." - Derrick

These details, however, were not preferred by all participants; one liked seeing an overall average of all food waste types as this would require less mental effort to read the information.

Overall, the display in figure 31 was preferred over the display in figure 30. There was a preference towards specific information on the types of waste.

Time granularity

Overall, there was a preference towards specific information on *when* waste has occurred. Most participants saw value in seeing daily waste amounts for the past days with the ability to switch from weekly to monthly to yearly windows. The visibility of daily changes presented in a graph was expected to raise questions and deeper reflections on what happened at a particular day. Although, a couple of participants also liked having the ability to look into daily, weekly and monthly averages because they feel that their interest or motivation to process specific information is likely to depend on their mood or time of the day. Some examples indicating the advantages of visualizing daily changes in a graph are:

"I like the second one better because you can process it on a deeper level. Instead of just being a number its ohh our waste went down, so thats good." - Alysa

"..just to see the fluctuations at each day. I guess whenever you see a peak, you would think: Oh, I wonder what happened, why so much food was wasted. So it sparks more questioning, more thought." - Hannah

Overall, the display in figure 33 was preferred over the display in figure 32. There was a preference towards specific information on when waste has occurred.

Unit of measurement

Almost all participants preferred seeing the monetary value of their waste. This might be specific for students who have tight budgets. The interest in costs might be due to the fact that food costs significantly more than water or electricity usage. A couple of participants, however, think costs might be too broad and were worried about how it would be calculated.

About half of the participants also liked to see the weight as a more specific measurement. This was linked to their associations of product prizes per weight. Weight as a specific measurement was preferred over servings: a serving was considered to be a more vague metaphor:

"For me, I would go for the kg but it depends on the person. I just always look at a lot of things in measures. I realize I used to buy 900 grams of meat for 13 dollars while I could have bought 1.4 kg of beef for 15 dollars. I am a very picky person if it comes to weight." - Derrick

"With servings you really have to draw a rough average, but with kg of food its specific. You know the value of what is there." - Farrah

"My definition for a meal from someone else is different because I don't eat that much. My friend if he cooks a package of minced meat it goes in two days but that can stay with me for a week. For him its like a meal and for me its like meals." - Bo

The preference for weight was not supported by all participants because of the lack of knowledge in how much they actually eat. In the end, participants agreed seeing the value of combining measurements units:

"The more information we have the better I guess. So we can sort of see that its not just one aspect that food waste affects. Food waste affects lots of different things." - Alysa

Overall, monetary incentives seem to be a motivating factor. However, especially with regard to other measurement units, preferences are not defined and differ between participants.

Comparison information

Almost all participants liked the combination of setting a goal and comparing their performance with others. With regard to setting goals, most were speaking about their own personal goal instead of a groups' goal as setting a common goal would require coordination with other group members. Setting a goal together was acknowledged to provide a good sense of community and therefore, should be supported:

"I don't want to be the one messing up for the whole team." - Isaac

In general, a green competition was expected to be very effective. It is also a common strategy used to engage residences in social activities within student associations at Simon Fraser University. Participants indicated, however, that comparison information would only be effective if in combination with the details for different food waste types (i.e., data granularity) so they can have insights in *what* to reduce:

"This screen itself doesn't do much. If I am not meeting my goal and I don't really know why it might not be that effective. I can try to brainstorm on why that happened but it wont be like ... change anything." - Bo

Hence, self comparison and social comparison were preferred. Including a green competition was expected to be more effective also because its a common strategy used to engage residences in social activities within students associations.

Self-control

Finally, Participants preferred a tablet visualization over an interactive bin as shown in figure 36 because a tablet visualization was considered more informative allowing users to self reflect on their own means. An interactive physical bin was expected to lead to frustrations rather than reflections. However, there were some aspects participants liked about it such as the responsiveness and the immediacy of the feedback at the time of disposal. Participants liked having feedback that triggers reflection with the right balance of interactivity and immediacy of the feedback information. Some examples of comments were:

"I think he tactile one would be very attention grabbing. Everyone would definitely know how much food is being wasted. Although I can see potential frustration if one person on the floor is throwing a lot, then they would be causing the problem for other people." - Alysa

"..is more self reflecting, its me who is motiving myself to change wanting to change.. as opposed to some robotic machine." - Farrah

In sum, although interactivity or immediate feedback is preferred, this feedback should intent to impact self-regulated reflection.

6.2.3 Discussion

In this section, design implications are presented as an extension and confirmation to the findings from *Chapter 5*.

Design Implications

Specificity in data. Participants confirmed their preference for specificity over averages. With the fact that participants seem to underestimate the amount of grains and starches (based on the questionnaire vs. visual inspections) and had a false perception of paper towels as contributing a great deal to the total amount of waste (based on the interviews vs. visual inspections), visualizations should include detailed information on the types of waste. This is expected to help in improving their perception of what is actually wasted and understanding of their behavior. It further aids in setting more detailed goals.

Specificity in time. Second, the display should present daily changes of food waste. It should also require minimum effort from consumers: a glance should be sufficient to trigger daily reflections on an instance of high food waste amounts. The problem with knowing the the weekly average, for example, is that it becomes hard to see and track back certain waste instances and their reasons. If waste is presented for within a shorter time window, participants would, for example, have been able to link the sudden increase of waste in the last day/week of the deployment with their finals.

Specificity in unit. Third, it is important to include a combination of measurement units to meet the needs of different people as each unit could have advantages and disadvantages. The interest in costs might be because food is generally expensive, especially in comparison to water or electricity where cost was shown to be small impacts (Delmas et al., 2013). Participants also expected costs to be even more effective when it is shown separately for the different food waste types (i.e., data granularity). This combination is expected to be more motivating, directive and hence actionable. Furthermore, consumers should be provided with a more specific measurement such as weight as opposed to a metaphor like servings because it is more open for interpretation (e.g., 600 grams of food is different in terms of servings for someone tall and male vs. someone small and female).

Social comparison as motivator. There should be a way for different individuals to set a common goal. Although, this could provide a better feeling of community, getting to a common goal can be a complex process for larger groups with independent users with possibly different goals. Perhaps, more focus could be given to a green competition instead which could target different floors within a building as well as other campus residence buildings. But comparisons should be fair in terms of number of occupants and similar type of users. Despite Vancouver being a Western culture, and hence a more individualistic culture, solely group feedback did reduce food waste. This means that the student residence culture could perhaps be considered collective such as the Japanese in the study of Midden et al. (2011). Furthermore, as participants did prefer additional social comparison information, this should only be positive social comparison information because negative social comparison information was found to increase food waste again. Or in case of negative feedback, suggestions should be presented instead.

Interactivity: constant reminding and responsiveness. Consumers should be given space to self reflect and choose to what level and when eco-feedback can have an impact on them. Technology should be designed in a way that feedback is immediate but without taking away consumers' control. For example, as the bin is being used the information gets updated on a tablet that is immediately visible. This would also provide better visibility of what an individual contributes.

Limitations

A limitation in evaluating these displays retrospectively is that they have not been deployed to understand their actual impact on food waste behavior. Future research should look into the impact of these design aspects individually for better comparisons in effectiveness. Furthermore, other design aspect has not been discussed such as the use of an agent, the variety of suggestions that could be provided or the use of dynamic visualizations. In *Chapter 7*, a concept for a suggestion for action is further explored.

6.3 CONCLUSION

This chapter explored more detailed design dimensions for eco-feedback displays to uncover how different representations of food waste feedback data may be useful in motivating consumers to prevent food waste and help raise awareness. For example, participants expected feedback to be more effective when provided immediately, calling for more interactivity and responsiveness at times of disposal. Participants also indicated that if it shows more specific information such as *what* and *when* something was disposed, they could better understand what they can do to prevent food waste. Specific information was expected to be more useful than the use of metaphors (i.e., which is commonly used in energy and water consumption) for deeper reflections, which could differ from person to person and day to day. Specific information could help indicate reasons of waste and ways for prevention. Participants also showed an interest in using eco-feedback as a way to reduce costs. Although costs for energy or water consumption might be too low and therefore less interesting (Delmas et al. 2013), in the context of food waste, cost was an important motivating factor which was also supported by Clear et al. (2016). Green competition was another motivating factor but only if it was positive in nature. These findings are based on insights from reactions after real long-term use of E-COmate confirming suggested implications discussed in *Chapter 5*.

7 SOCIAL RECIPES

In this chapter, a second concept is introduced and evaluated as part of the community-based social system. This concept, called Social Recipes, aims at encouraging food sharing by suggesting groups of related consumers recipes that are based on ingredients from different individuals or households. To evaluate Social Recipes, 3 user studies were conducted to see how it could raise awareness and reduce food waste. In the first two studies, expected impacts of the concept were explored. The third study was a home deployment, where Social Recipes were sent using technological probes for a more realistic experience. The findings informed further design implications for the system. Overall, the aim of this chapter is to contribute to an understanding of how Social Recipes could impact consumers and hence, how to design a community-based social (recipe) system that can be integrated in consumers daily activities for effective but more pleasurable food waste prevention.

7.1 FROM AWARENESS TO ACTION

Eco-feedback has been criticized for not providing the user with explicit action possibilities (Brynjansdottir et al., 2012; Maitland et al., 2009). Also in *Chapter 5*, interview participants showed the desirability of a system that goes beyond than just supporting awareness. In this chapter, a second concept is presented called Social Recipes, which aims at providing an action possibility in addition to feedback information (See figure 37). The prospective of the concept is to collectively prevent food waste by encouraging collaboration and food sharing. Apart from this altruistic aim, the concept is expected to incentivize people to

This chapter contains parts published in:
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Lim V., Yalvaç, F., Funk M., Hu J., Rauterberg M., Regazzoni C., Marcenaro L. (2014). Design implications for a community-based social recipe system. *In Proceedings of the World Congress on Sustainable Technologies* (pp. 19 - 26). New York, NY: IEEE.
Lim, V., Funk, M., Regazzoni, C., Marcenaro, L., and Rauterberg, M. (2017). Designing for action: an evaluation of Social Recipes in reducing food waste. *In International Journal for Human-Computer Studies, 100*(2017), 18 - 32.

share, cook and enjoy food together. According to Maitland et al. (2009), systems designed for action were argued to have impacts on creativity, pleasure and nostalgia, gifting, connectedness and trend-seeking behaviors. He suggested that for persuasive technology to be successful, it should be designed to encourage action. In sustainability research, the nature of the expected behavioral change is often unspecified (Brynjardottir et al., 2012). The central aim of this chapter is to contribute to an understanding of how Social Recipes could impact consumers and hence, how to further design the community-based social system that can be integrated in consumers daily activities for effective but pleasurable food waste prevention.

7.1.1 Introducing Social Recipes

With emerging technology, the envisioned system as shown in figure 38, allows users to log and track available in-home ingredients as well as their wasteful behaviors through appliances in the kitchen such as a fridge and a bin. Based on this information, the system is expected to help users to redirect behaviors, through social influence strategies, towards more sustainable food related practices in terms of food waste. Besides supporting awareness of wasted foods (i.e., such as E-COmate), a main function of the system is to detect food availability as well as potential food waste and respond by suggesting Social Recipes. With these particular recipes, the intention is to encourage the use of high-risk ingre-

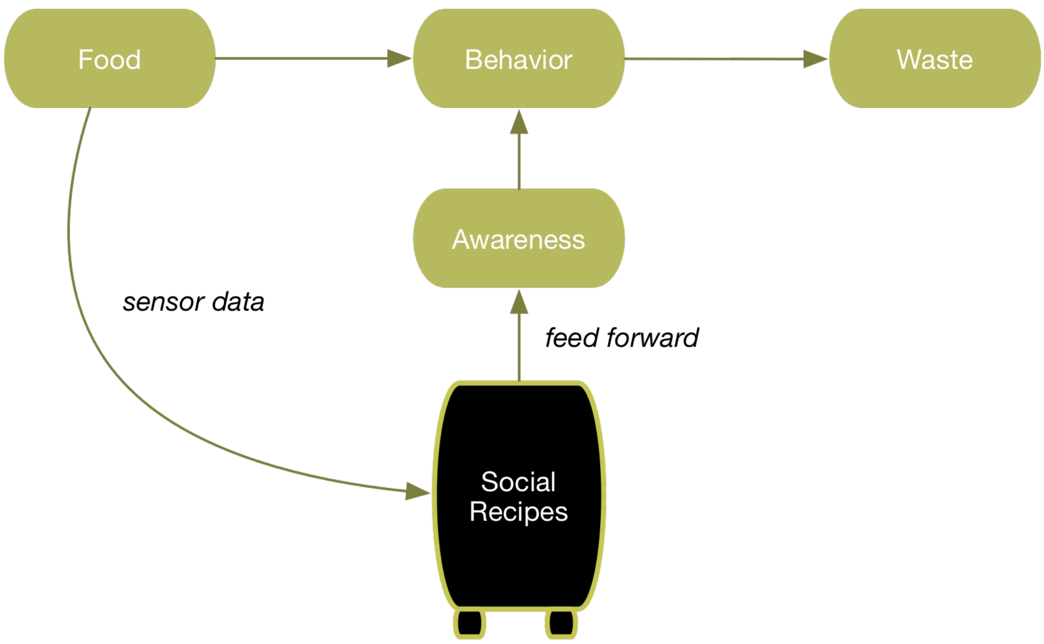

Figure 37.: The input value (i.e., food) is used to form suggestions to control the output value.

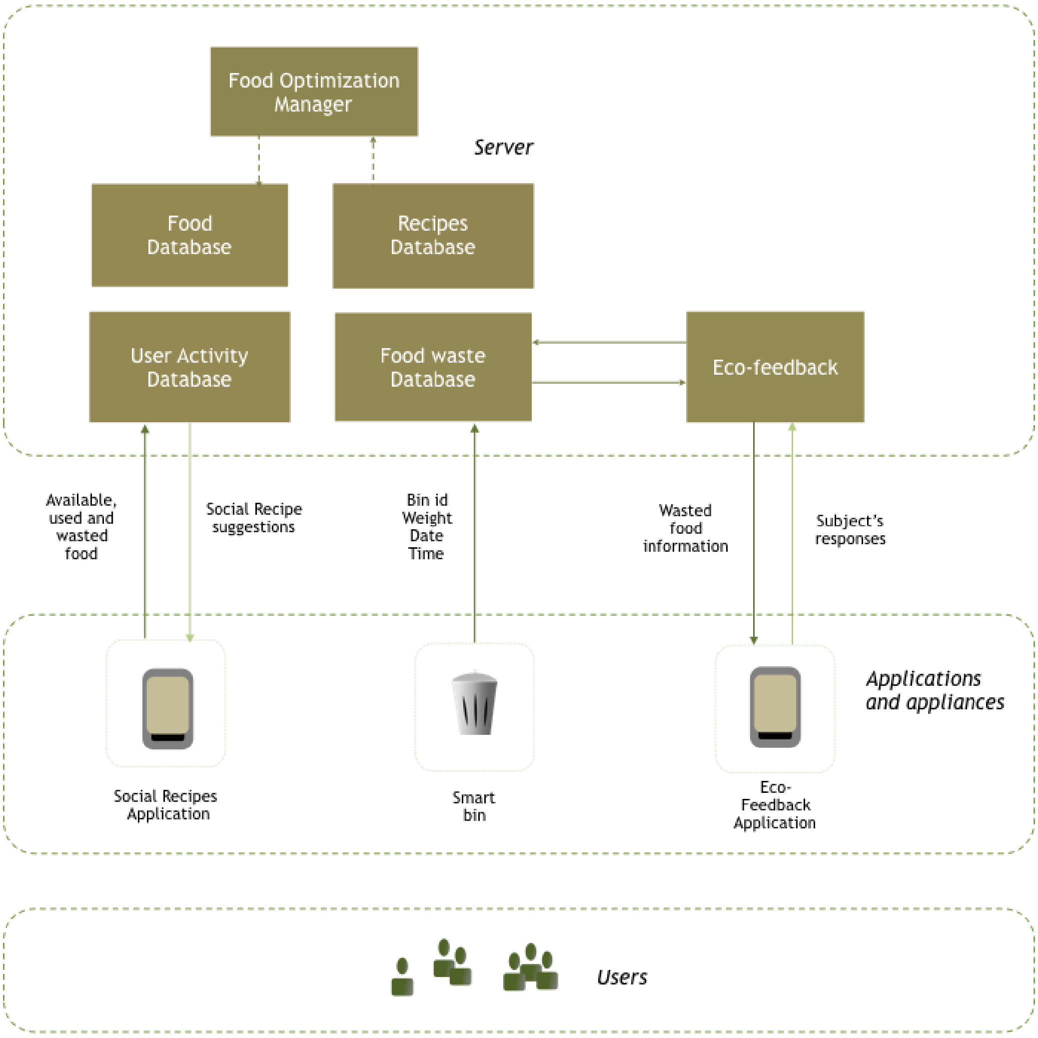

Figure 38.: A global overview of the community-based social system. With the Social Recipes application the available, used and wasted ingredients from users are collected, which is stored in a server. Food availability is then handled by a food optimization manager who selects and sends Social Recipes suggestions to users. The wasted ingredients are also collected by a smart bin. The collected data is processed by an eco-feedback manager and fed back to an eco-feedback application for data visualization visible to all users.

dients owned by different individuals in a creative and social alternative. Additionally, the system could provide information of food waste types and amounts (i.e., eco-feedback) to improve understanding of wasteful behaviors and as an additional feature to encourage users to use the suggested recipes. The concept of Social Recipes can provide moments for collaboration, creativity, connectedness, and inter-cultural encounter, which is in accordance with recent suggestions on exploring the roles of collectivism and community for food sharing practices as a way to reduce food waste (Comber et al., 2013; Silberman et al., 2014). With this concept, social activity is used to discourage food waste, which is also in accordance with the celebratory technology described in (Grimes and Harper, 2008).

7.2 THE SHARING ECONOMY

The concept is inspired by the emerging sharing economy. Some well known examples of sharing concepts are Airbnb or NightSwapping for accommodation, and Uber or Blablacar for car rides. These communities provide benefits for providers and receivers in terms of costs, personal and social experience, and for Blablacar also in terms of sustainability. Despite their successes, the HCI community has insufficiently explored the potential of food sharing. Although, there has been previous work in the area of human-food interaction that celebrates the positive relationships people have with food, most do not target food sharing in particular. For example, the designers of I8DAT aimed at producing actionable knowledge through the sharing of food images for educational purposes (Choi et al., 2011). Similarly, the Hate Waste Love Food [1] application was developed for recipe sharing while 'on-the-go' but not actual food. With Social Recipes, the aim lies at producing actionable knowledge but from the perspective of what is available from a group of users to encourage collaboration. Examples of food-related applications that support a different type of sharing includes Foodmunity and Eatwell. Foodmunity (Gross et al., 2011) is a platform through which community members can share personal experiences about meals. These personal experiences may focus on a variety of topics such as culture, religious events, or family. The main aim of the platform is to share these experiences with others as a basis for exposing people to the new and the unknown. EatWell (Grimes et al., 2008) allows users to create voice memories describing how they have tried to eat healthfully in their neighborhoods (e.g., at local restaurants) and listen to the memories that others have created to facilitate a sense of community empowerment. Like Foodmunity and EatWell, Social Recipes aims at facilitating a sense of community. However, it also aims at encouraging users to *actually* get together, share their ingredients, and collaborate in making food together in a sustainable

1 www.lovefoodhatewaste.com

and social manner.

Across the globe, communities for food sharing are emerging but do not involve technology. For example, the food-is-free project[2] helps people gain independence from the agricultural industry. It focuses on community building and gardening where those involved learn how to connect with neighbors through front yard community gardens. There are also communities where farmers and retailers can offer, and consumers and organizations can collect free food items such as described by Ganglbauer et al. (2014). Social Recipes builds on this idea of free food sharing but from the angle of in-home availability and smart home technologies. Although there are applications that do support food sharing such as LeftOverSwap (Farr-Wharton et al., 2014) and ShareYourMeal[3], these do not aim at facilitating this sense of close communities. Instead they allow users to exchange or share cooked leftovers or meals for a small price without facilitating further interactions. Next, studies are discussed conducted to evaluate the potential and impact of the concept.

7.3 PERCEIVED IMPACTS OF SOCIAL RECIPES

Social Recipes was evaluated in 3 studies. This section discusses only the first 2. In the first study, participants were asked to keep track of their food waste for a month and were interviewed about their opinion about the concept at the end of the month. Details on their wasted items during the study were presented and discussed in *Chapter 2*. In this chapter, only their reactions towards the concept are discussed. The second study was a focus group, where participants discussed the expected impacts of the concept without relating it to the negative sides of food (i.e., food waste).

7.3.1 Methodology

To explore expectations on advantages and distracters of Social Recipes, the following description of the concept was presented to participants in the end of an exploratory field study and in the focus group: *'Imagine a system that knows which foods you have in your house, which foods your friends have in their homes, and that can suggest you to get together with your friends to make a recipe with the available ingredients without having to go to the grocery store.'*

2 www.foodisfreeproject.org
3 www.shareyorumeal.net

Participants and procedures from the exploratory study

In the first study, an exploratory study, 27 participants logged their waste and their reasons for a period of a month (See *Chapter 2* for more details). In *Chapter 2*, some findings from this study were presented on the most common type of waste and reasons, which showed the relevance of targeting dinner items collectively. At the end of this study, participants were provided a verbal description of the concept in a hypothetical fashion to gather their expected experiences and initial ideas.

Participants and procedures from the focus group study

The second study, a focus group, was a follow up of the exploratory study. A double-blind focus group study was conducted with six PhD students and one moderator. The main objective was to see how participants think about Social Recipes if the concept is not explicitly linked to the aim of reducing food waste like in the exploratory study; what advantages or disadvantages do they foresee in this particular concept? The double-blind procedure was to keep the moderator in a neutral position to guard against experimenter bias and influences. Participants were recruited with the following requirements. They all had to live with at least another person at home, cook at home at least three times a week, eat or cook together with friends at least twice a week, and they had to do groceries themselves. All participants were from China, but living in the Netherlands. The choice for selecting Chinese students is because of their cooking culture as they cook regularly in social settings. As the world largest emerging economy, China is suffering high waste amounts at the consumer level comparable to Western countries (Liu et al., 2013). All participants were compensated with lunch, which they received during the focus group session.

The focus group session started off with some general warm-up questions about food experiences. Next, participants were asked what would make a good food-related experience to get insights in what they value most. This was followed by a question about which food items they have available at home and whether they would share these with other people. They were then presented with the concept of Social Recipes using the same description as in the exploratory study and asked (1) how they see the system would impact them and (2) who they would prefer to use the system with. The focus group session was attended by two researchers who made notes. The session was video recorded to support the process of analysis. A thematic analysis was used to explore reactions towards the concept.

7.3.2 Findings from the exploratory study

Most participants were enthusiastic about the concept of Social Recipes, but also noticed disadvantages or detractors. Reasons for using such a system relating clearly to its *advantages* were for habitual purposes, awareness, creativity and surprise, and coordination:

- *Awareness.* A number of participants consistently threw away the same type of vegetables because they had difficulties in predicting how long the item would be edible at the time of purchase. For this reason, they saw potential in having a system that would help remind or motivate them to use items with a constant likelihood of being wasted. For other participants, items were wasted because participant just simply forgot them due to a busy lifestyle. This was especially the case for discounted perishable food items (e.g., economy packages or sales). Therefore, participants expected a system such as Social Recipes to improve awareness and help remind them of what they have available. Social Recipes could help increase awareness of the availability of items that gets wasted most likely (i.e., vegetables) and remind or encourage its use before it gets bad (i.e., the most common reason given for disposal as discussed in *Chapter 2*).

- *Creativity and Surprise.* Participants did not only foresee how Social Recipes could help remind them of what is available but also how it could inspire them. It could trigger creativity around cooking as it could be used as inspiration for other recipe possibilities. Moreover, they expected the content as well as the timing of the suggestions to be positive surprises while encouraging spontaneous and fun meet-ups around cooking. This is in accordance to Maitland's (2009) expectations on designing for action.

- *Coordination.* Participants also foresaw the usefulness of Social Recipes in supporting coordination between the individual members of an household around shopping as well as cooking. They expected it would provide better visibility of availability within a group without the requirement of intensive communication such as calling each other. Participants often had similar items available that could have been shared instead. Social Recipes could help in preventing users from buying similar or already available items. This is also in accordance to Ganglbauer et al. (2012) suggestion to design for collaboration to organize daily practices around food and ultimately reduce food waste.

Participants also expressed *negative* attitudes towards Social Recipes:

- *Preparation values.* A reason for not using Social Recipes might be when users cook extensively and spend time on cooking individually for others. A couple of participants valued cooking as an individual activity which they think should be done in advance before a guest shows up for dinner. This was considered to be a means to show hospitality. However, this preference was also impacted by the size of their own kitchen.

- *Travel distance.* Another reason why participants might not use Social Recipes is the distance they need to travel in order to get together with friends for dinner. Participants might prefer going to the grocery store that is nearby over collaborating with friends as it could be more convenient and less time consuming. This could, however, depend on someones personality or current mood rather than the actual travel distance.

7.3.3 Findings from the focus group study

Generally, participants agreed that the presence of other people was what makes a good food experience. What they enjoy the most was having food with friends and the activity of preparing food for others. The social company was most valued. Most participants in this session were enthusiastic about the concept of Social Recipes. Like participants from the exploratory study, they foresaw how it could impact food waste and positive interactions but also noticed disadvantages or detractors. Reactions which clearly relate to *advantages* were on connectedness, creativity and knowledge:

- *Connectedness.* Participants liked how Social Recipe suggestions could create the feeling of being connected with others through the in-home available ingredients. These suggestions, which is expected to come in as surprises at random moments, could show users more opportunities to see friends, share private moments and grow closer to each other. The collaborative aspect in saving food together brings a sense of community.

- *Creativity and Knowledge.* Another aspect participants liked was that Social Recipes might help them in gaining new cooking skills. Users foresaw how they could learn from the suggestions from the system as well as from each other while they cook together. It would create an opportunity for the exchange of knowledge around cooking practices. The suggestions were expected to inspire creativity and to initiate conversations.

Participants also expressed negative attitudes:

- *Trust.* Specifically, two types of trust were identified. The first type of trust was in the suggestions provided by the system: some participants indicated the importance of receiving suggestions according to the foods they like with nutritional value. The second type of trust was in the way others take care of their food items before they are shared. For example, where they have placed or saved the items before it is shared.

7.3.4 Discussion

The two studies so far showed how a community-based social (recipe) system could impact groups of consumers and what issues it might raise. Although, findings showed potential of such a system with impacts on awareness, creativity, coordination and collaboration, knowledge and connectedness, detractors such as, preparation values, travel distance and trust might prevent consumers from using it.

Design implications

The findings above inform implications on the convenience of location and the relevance of building trust.

Convenience and consideration of location. The system should suggest the location for cooking based on the size of the group that is suggested with Social Recipes so that the place can accommodate the number of people that are sharing. For those who prefer to cook for others individually instead of collaboratively, the system could allow users to provide their preference around the activity of cooking. With Blablacar[4], for example, users can indicate whether they like hearing music or chat while driving. These options should also be considered in a concept like Social Recipes. Furthermore, travel distance should be minimized for all individuals receiving a suggestion. If a supermarket is located closer than a friend, users might find it easier and more convenient to go to the supermarket. Therefore, the system should consider the distances between users and to supermarkets. For example, to increase the attractiveness of Social Recipes, the system should consider ingredients from users who are located not much further than the closest supermarket or it should minimize the distance to be traveled by all users. Also, a constraint value could be defined so that users do not need to travel more than a predefined distance.

Building of trust. Trust could be a challenging issue for design, but critical for the acceptance of food sharing technology. Suggestions can be provided for both types of trust identified above. For example, to deal with the first type of trust, the system could construct user profiles based on what users bought before and provide recipes with familiar food items that are nutritionally balanced. Adopting healthy eating patterns are expected to have great additional effects on

4 www.blablacar.com

sustainability than reducing food waste alone (Rutten, 2013). For the second type of trust, the system could allow users to find and invite their friends, or connect with potential future friends who have the same taste or food interests. Moreover, the system could allow them to set a parameter for the number of users for receiving a recipe suggestion. This is expected to increase acceptance rates, as it might be more difficult to coordinate with more people.

Limitations

This study comes with limitations. First of all, in the first study, participants were aware of the purpose of the study, which could have had impacts on their comments. This was considered in the focus group where a double blind procedure was applied. In both studies, however, the findings were self-reported and how it would actually impact behavior is unclear. Therefore, in the next study, participants were provided with a closer experience of Social Recipe suggestions in a deployment study.

7.4 OBSERVED AND REPORTED IMPACTS OF SOCIAL RECIPES

In the third study, prototypes were developed and deployed at home to provide a closer experience of the concept in a real environment in order to explore actual reactions (Hutchinson et al., 2003). This was done with a Wizard of Oz approach (Dow et al., 2005), a widely used method in human-computer interaction research to explore user interfaces for pervasive, ubiquitous, or mixed-reality systems that combine sensing and intelligent control logic. With this approach, the logic behind the user interface interactions are enacted by a person rather than a system. The objectives were to explore (1) the impact of Social Recipes and (2) how eco-feedback could add in supporting food waste-related behavior. The ultimate goal was to further provide design implications for development based on triangulation of findings from all three studies discussed in this chapter.

7.4.1 Methodology

Study Design

The study took place for a month. In the first week, participants were given time to get acquainted with the following probes; a mobile application for food logging and an augmented bin to monitor food waste with eco-feedback (i.e., the second prototype of E-COmate with visualization 1). Whatsapp chat groups were used for all communication with participants such as for instructions, questions, comments, and anything else participants like to share such as pictures.

Group	Name	Age	Gender	Housing	Intervention Type
A	Andrea	23	M	same	SR & EF
	Alan	25	M	house	
	Anton	24	M		
	Adam	25	M		
	Aykan	23	M		
B	Brenda	24	F	same	SR & EF
	Beatrice	23	F	house	
	Bianca	23	F		
	Beth	21	F		
C	Chris	24	M	same	SR
	Colin	20	M	house	
	Carla	24	F		
D	Dena	24	F	separate	SR
	Daisy	28	F	houses	
	Diana	26	F		

Table 12.: Participants Demographics. SR = Social Recipe suggestions, EF = Eco-feedback. Pseudonyms are used to refer to participants.

Whatsapp was also used to send the Social Recipe suggestions according to the Wizard of Oz approach.

Participants

Four groups of participants were recruited with a total of 15 individuals (students and young professionals) between the age of 20 and 28. Each group consisted of 3 to 5 individuals living together with the exception of 1 group who were friends living separately (See table 12 for the demographics). Participants were recruited in the same manner as in the focus group study. With the exception of 1 group, participants were not required to travel to share food so other design implications could be discovered. All groups of participants received Social Recipes of which 2 groups also received eco-feedback. In this study, pseudonyms were used to protect each participant's identity.

Technological probes and procedures

Technological probes were developed to evaluate Social Recipes and the additional impact of eco-feedback, the two main proposed concepts of the overall envisioned community-based social system. These probes were developed to capture in-home availability and food waste patterns from consumers, and to deliver Social Recipe suggestions and eco-feedback in situ.

Probe 1: Food logging and Social Recipe suggestions. In order to create Social Recipe suggestions, in-home ingredients need to be tracked. To do this, a mobile application was developed (See the interaction between the Social Recipes application, server, and users in figure 38) for iOS and Android in a hybrid approach using PhoneGap, which participants were asked to install on their phones in the beginning of the study. The mobile application was written in JQueryMobile, HTML and CSS for the user interface and JavaScript for the user interaction. Data from the users were stored locally using a SQLite database engine and sent to a server implemented with the PLAY framework.

In the beginning of the study, participants were instructed to create a user account and use the application to log their in-home food availability on a daily basis (See figure 39 for the user interface). To limit data entry, they were asked to log only ingredients for dinner that were available for over 24 hours. In the application, participants could search for ingredients through images, and select and add them to a stock list (in-home availability) or wish list. The wish list was only meant for ingredients they plan to buy, which were automatically moved to the stock list when the purchase was confirmed. In both lists, users can enter the amount of each item in weight, numbers or liters. If an item in the stock list was disposed, users could delete it. This moves the item to the bin folder where reasons for disposal can be further indicated.

The data entered in the application by the different individuals within each group were used to form Social Recipe suggestions. These suggestions were created and sent to participants manually with Whatsapp and according to the Wizard of Oz approach. This approach is a widely used method in human-computer interaction research to explore user interfaces for pervasive, ubiquitous, or mixed-reality systems that combine sensing and intelligent control logic (Dow et al., 2005). To generate suggestions, the following steps were taken: (1) take items with a sufficient amount (more than 100 grams), (2) use a database for recipes[5], (3) initially, consider all available items, then (4) exclude items that are newest based on starting date until at least 3 recipes are found, (5) select a recipe with the least extra items to add, and (6) provide multiple suggestions if possible. Each suggestion included a picture of the recipe, the available ingredients to use and from which owner, and additional items to add as shown in figure 40. A suggestion was send to the groups of users once a week through Whatsapp.

Probe 2: Monitoring of food waste amounts and eco-feedback. An augmented bin was developed for the measurement of food waste weights for each group of participants (See figure 41) and to evaluate the additional impact of eco-feedback

5 http://www.ingredienten.nl/recepten

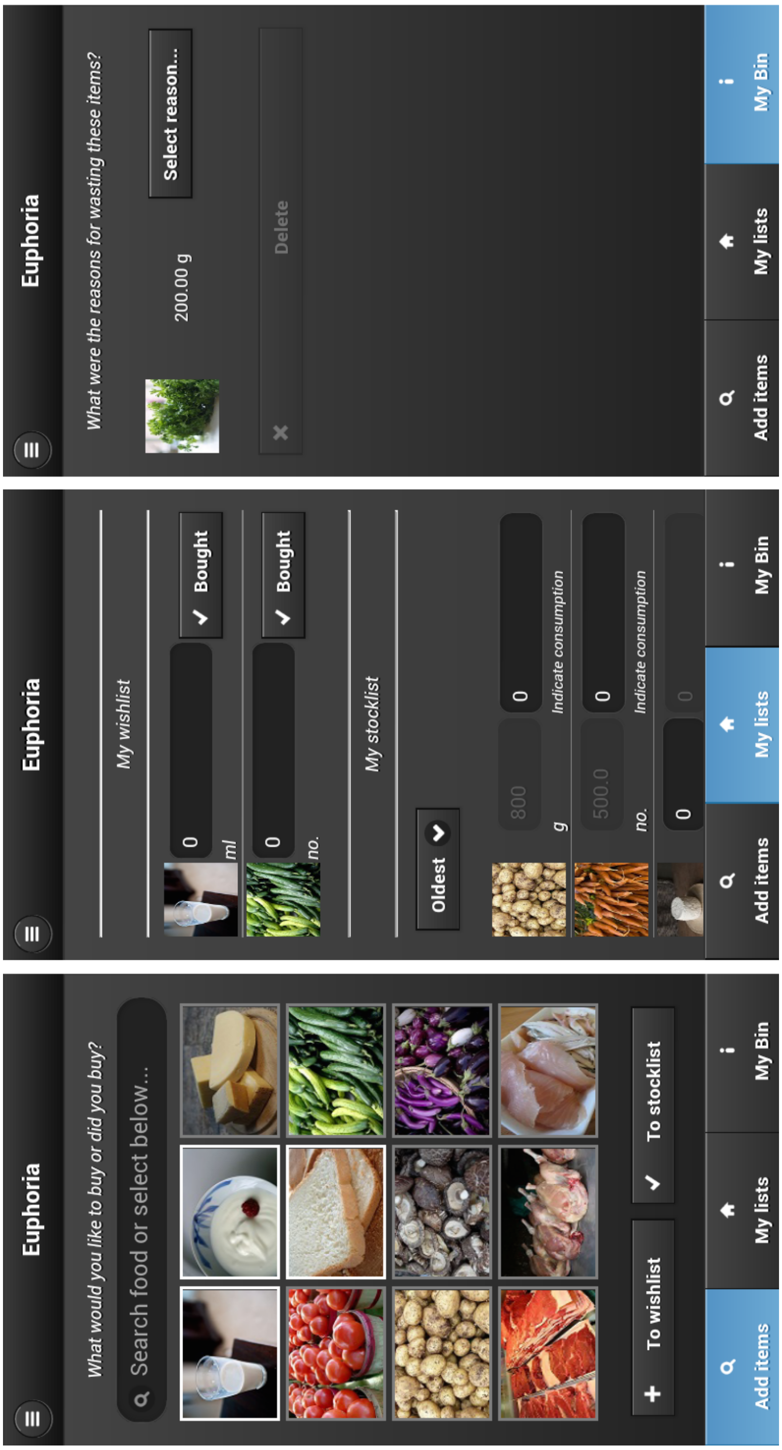

Figure 39.: The mobile application user interface for ingredients logging. Presented from left to right: the search list, wish and stock lists, and the waste list, respectively.

(See the interaction between the augmented bin, server, eco-feedback application and users in figure 38). The bin consisted of a Dymo M5 USB postal scale, a 5 liter trash bin and a Raspberry Pi with a Wi-Fi module protected with a laser-cut wooden enclosure. The Raspberry Pi requested a weight measurement from the scale until a stable weight was found via USB, which was sent to a remote server. See *Chapter 4* for further details on the eco-feedback concept. Participants were instructed to use the bin for all organic waste that was still edible or once edible and were provided with a list of items they were *not* allowed to throw. Furthermore, they were instructed to reset the bin every time it gets emptied. These instructions were written on the bin, but they could also text using Whatsapp for any help along the study.

Figure 40.: These are two screenshots with examples of how a *Social Recipe* suggestion was delivered. Each suggestion included a picture of the recipe, the available ingredients that can be used and from which owner, and additional items that be added.

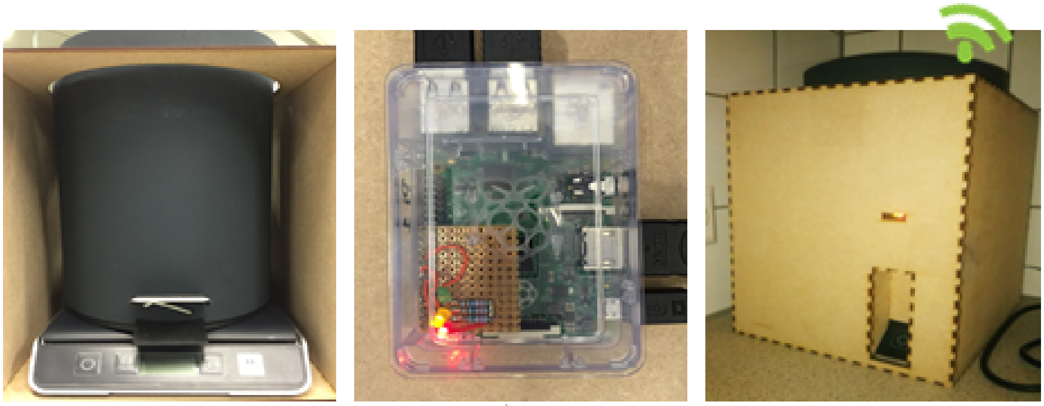

Figure 41.: Prototype 2 with the wooden enclosure.

The data collected with the bin was fed back to 2 groups through an application installed on a tablet computer, which was placed with a tablet holder in a visible location in the kitchen. The application displayed the amount of food waste in the number of servings: every 200 grams of waste was calculated as 1 potential serving. In the last 2 weeks, the display also showed what others wasted in addition to participants' own food waste amounts. This amount were generated by taking a random percentage between 40 and 110 percent of participants' own food waste amounts, so that most of the time participants were receiving negative feedback. This was done to make sure that both groups were receiving similar feedback. However, participants were informed that social comparison information was coming directly from another group of participants to trigger competition.

Data collection and analysis

After the deployment, participants were asked to fill out a post questionnaire with Likert scale questions and open-ended questions (See Appendix F) to evaluate the impact of Social Recipes and eco-feedback on food-related behaviors, awareness, reflection, coordination and communication (i.e., social interactions). Additional questions aimed at gathering their level of motivation to change behavior and to see whether they find the concepts effective in reducing domestic food waste. Answer options ranged from very much to not at all, with items score contribution from 7 to 1, respectively. During the deployment Whatsapp chat groups were used to send Social Recipe suggestions and for free text messaging to gain insights in their spontaneous reactions towards the suggestions. The reactions or comments in the Whatsapp chat and questionnaire were analyzed and categorized into themes and triangulated with findings from the first and second study. Based on these results, further design implications are suggested for the proposed community-based social system. To test the viability of the interpretation of the findings and suggested implications, a respondent validation was conducted (i.e., member check).

7.4.2 Findings from the home deployment study

Usage Descriptives

This section describes the usage of the probes discussed earlier. For the mobile application, 622 actions were counted with 5 action types: opening the application, the users' list (wish and stock lists), the waste list, the users' profile, and sorting items in the users' list. 251 items were entered in the users' list of which 78 items were wasted (dairy: ci. 3705 grams/liters, vegetables and fruits: ci. 3227 grams and 24 pieces, grains and starches: ci. 7060 grams, meat and fish: ci. 950 grams). An average of 332 grams of food waste went into the bin per person per week (excluding 2 participants who were only using the mobile application).

Emerging themes

In this section, findings are presented from the questionnaire scores (perceived impact) and the free text messaging (observed impact). It should also be noted that only the questionnaire items were considered in the discussion when at least 50% of the participants have given a score of a 5 or higher on the Likert scale or when scores were unexpectedly low (See table 13). The findings are discussed around the broader themes of what participants from the previous two studies expected to experience.

- *Awareness.* Initial reactions towards the suggestions showed interest and curiosity in the Whatsapp chat;

  "I think it is a good plan." - Andrea
  "Great idea! Look delicious! Could you send the recipe?" - Dena
  "I will indeed keep the broccoli for a tortilla, that is a good one! I think I will make that, I still have coconut left!" - Diana.

  A total of 10 positive reactions towards Social Recipe suggestions were received (out of 36 if each person would respond to each single suggestion). This indicates a positive attitude towards the suggestions by a number of participants. However, they were not utilized. For example, in the post questionnaire, several participants reported being more aware when they received Social Recipes, but in the sense that it helped them remember their own current food availability. This self awareness turned into actions related to how they were dealing with their leftovers. For example, Brenda felt more motivated to keep the leftovers for an extra day and ate it at lunch

Question	7	6	5	4	3	2	1	Median
1a. Do Social Recipe suggestions influence your individual behavior regarding food planning?	0	1	2	0	1	5	1	2.0
1b. Do Social Recipe suggestions influence your individual behavior regarding food purchasing?	0	1	1	2	2	4	0	3.0
1c. Do Social Recipe suggestions influence your individual behavior regarding food preparation?	0	1	1	2	1	5	0	2.5
1d. Do Social Recipe suggestions influence your individual behavior regarding dealing with leftovers?*	1	2	2	3	1	1	0	4.5
2a. Do Social Recipe suggestions influence the group behavior regarding food planning?	0	1	1	3	1	3	1	3.5
2b. Do Social Recipe suggestions influence the group behavior regarding food purchasing?	0	0	2	3	1	4	0	3.5
2c. Do Social Recipe suggestions influence the group behavior regarding food preparation?	0	0	1	2	1	6	0	2.0
2d. Do Social Recipe suggestions influence the group behavior regarding dealing with leftovers?*	1	1	3	2	0	3	0	4.5
3. Do Social Recipe suggestions affect awareness on overall food practices?*	1	0	5	3	0	1	0	5.0
4. Do Social Recipe suggestions affect coordination within your group regarding overall food practices?	0	0	1	2	2	3	2	2.5
5. Do Social Recipe suggestions affect communication within your group around the topic of food?*	0	2	3	1	2	2	0	4.5
6. How much is your level of motivation to change your behavior around food practices at this point?*	1	3	3	1	2	0	0	5.0
7. Do Social Recipe suggestions support reflection?	0	1	3	3	2	1	0	4.0
8. Are Social Recipe suggestions efficient in reducing overall food waste?	0	0	1	4	2	1	2	3.5
9. Do you consider Social Recipe suggestions to be effective to reduce overall food waste?	0	1	3	2	2	2	0	4.0
10. Does Eco-feedback provide an additional impact on your individual behavior?	0	1	2	1	1	0	2	4.0
11. Does Eco-feedback provide an additional impact on the group behavior?*	0	3	1	0	1	0	2	5.0
12. Does Eco-feedback provide an additional impact on awareness?*	1	0	3	1	0	0	2	5.0
13. Does Eco-feedback provide an additional impact on coordination?	0	0	0	0	2	2	3	2.0
14. Does Eco-feedback provide an additional impact on communication?	0	2	1	2	0	1	1	4.0
15. Does Eco-feedback provide an additional impact on reflection?	0	3	0	1	1	0	2	4.0
16. Does Eco-feedback provide an additional impact on efficiency?*	0	1	3	0	2	0	1	5.0
17. Does Eco-feedback provide an additional impact on effectiveness?*	0	2	2	0	1	1	1	5.0
18. Indicate how much impact the display without social comparison had on you.	0	0	1	3	1	1	1	4.0
19. Indicate how much impact the display with social comparison had on you.*	1	2	1	1	1	1	0	5.0

Table 13.: Summary of frequency distribution for questionnaire 3 (See Appendix F). * indicates questions where at least 50 % of the participants have given a score of 5 or higher on the level of perceived influence.

and Chris searched for other recipes online. Hence, instead of collaborating with other users in the group, participants took actions individually.

- *Knowledge.* Another main finding was that Social Recipe suggestions triggered the exchange of knowledge between the participants in a group. For example, they reported to have more offline conversations about what to cook, what has been cooked and ways to avoid food waste. This was also visible in the Whatsapp chat of group D, who were not living in the same house. A specific instance was a conversation on how to store coriander. When a Social Recipe was suggested including coriander for a second time (i.e., as it was suggested in a previous recipe the week before), Diana was surprised and asked why Dena still had coriander available. She responded with an explanation on how she usually stores it, so that she can extend its use. She shared a picture with the herb in the freezer and explained to Diana that she would only cut off a small amount each time she needed it. This was a very useful tip for Diana. A Social Recipe suggestion resulted in a gain in knowledge on how to store food. Other topics of conversations found online were on how to cook with specific ingredients. These triggered conversations should be seen as another means for raising awareness (i.e., person to person), which could have an influence on behavior but indirectly because in general people are easily affected by the social environment, approval and norms (Beretta et al., 2013; Buzby and Hyman, 2012; Milfont et al., 2006).

- *Coordination.* Based on the evaluation from studies 1 and 2, some instances of coordination were expected. Although, conversations around food were reported and observed, these did not result into any instance of coordination or cooperation within the groups. Despite that participants had visibility in how they could cooperate in making a recipe together, this had no impact on actually using the ingredients together. Most participants reported no influence on coordination or cooperation, for example because of plans they already made. This could further mean that the suggestions might be coming in too late or at a wrong time. Other than timing, the recipes were either unpractical or participants just did not feel like making it. Consequently, Social Recipes were only perceived as efficient or effective for food waste prevention by five participants.

The role of eco-feedback

The eco-feedback probe had an impact on participants' awareness especially when it showed social comparison information. Almost all participants who experienced the eco-feedback display indicated social comparison to be an important motivating factor. Unlike Social Recipes, eco-feedback was perceived as more effective in preventing food waste.

- *Awareness and social inclusion of technology.* The two groups of participants with eco-feedback were found to value the competitive aspect of the probe. For example, group B checked up on each other when wasted amounts suddenly raised:

  "It was funny to notice that we asked each other whether somebody recently threw away a lot of food when the eco-feedback increased a lot within one day." - Brenda

  Also group A showed monitoring behavior in the Whatsapp chat group, but towards the accuracy of the visualization. The group started questioning how it was calculating the total amount of wasted servings. Due to the high amounts that was visualized, participants requested a data check for noise twice. This was likely due to the social comparison information and the competitiveness that it triggered. For example, an indication of competition as a motivator for monitoring waste was the following comment:

  "We want to win." - Alan

  Accordingly, they were interested in being able to track back the food waste amounts so they could check what happened at what day and reflect on it. Another aspect that might have had an impact on their alertness, is the fact that they personified the bin as a living entity. Group A named their bin 'Freddie' using a sticky note right after installation. This name was repeatedly used by all participants to refer to the bin:

  "Freddie enjoyed the dinner tonight." - Alan

  One of the participants also mentioned that at the end of the study they felt like Freddie was getting too much food and that they wanted to stop feeding him. Personification might have helped in the presence of the eco-feedback system in participants daily environment, and hence awareness.

7.4.3 Discussion

Based on these findings, several implications are presented here to improve the design for food sharing. These were also reported back to participants for validation by means of member checking.

Design implications

Food sharing technology should be designed in a way that the suggestion for sharing could be seen as an option for users to deal with their in-home ingredients and allow for the setup of personal preferences. For example, so that users could first get familiar with the system for individual purposes. Second, it should aim at supporting the exchange of information between users to trigger conversations rather than on coordination. Food sharing technology could target the knowledge building in particular to motivate consumers. Finally, it should also include feed back information with social comparison as an additional motivator to engage users in reducing food waste.

Flexibility and the power of choosing. Food sharing technology should be designed in a way that suggestions for sharing can be seen as an option for users to deal with their in-home ingredients. For example, when participants prefer to cook and eat by themselves, which could further depend on several factors such as personality, the occasion, mood, or relationship with the others in their group, they should be able to find recipes based only on their own ingredients. In this case, users could just receive a simple reminder that their ingredients are sufficient for certain recipes that are available in the database. They could then, for example, take another step by looking at a variety of suggested recipes and further filter out preferences for new ways to cook (e.g., such as by selecting Social Recipes). A similar concept on innovative cooking is being developed by IBM, Chef Watson[6]. Their concept allows users to select their ingredients, but also the type of kitchen and the level of surprise or creativity using a database with more than 9000 recipes. Social Recipes or any type of food sharing concept, could be such an additional option. Moreover, incentives could be provided to motivate food sharing by including, for example, the cost benefits in comparison to when they choose not to share. When participants were asked if Social Recipes should provide multiple options based on personal preferences, almost all participants (70%) agreed.

Supporting information exchange and communication. When technology aims at supporting the practice of food sharing, it should also aim at supporting the exchange of information between users. The social environment could be of valuable input for food-related decision-making. People can easily adopt, imitate or learn from others close to them and technology can take a mediating role in this. Hence, Social Recipe suggestions could trigger or initiate a topic for conversation. When participants were asked if Social Recipes should support communication among those who are suggested with a recipe, 60% of the participants agreed. A reason for not agreeing with this implication was that the ability to see each others' ingredients is already valuable and does not require much further com-

6 www.ibmchefwatson.com

munication.

Settings preferences for the suggestions. To deal with the impracticality or dislikes of the suggestions, users should be able to choose when to receive suggestions (e.g., for a certain day or period), set preferences for the type of recipes, and perhaps also set who they like to share food with. As participants do not change plans, food sharing technology could, for example, allow the user to request a Social Recipe suggestion at any instance when there is no plan. Moreover, timing of suggestions could also be linked to an individual's schedule. However, when participants were asked whether users should be able to set when they like to receive Social Recipe suggestions, answers were neutral.

Feed forward and feedback. A community-based social system should include feed back information with social comparison as an additional motivator to engage users to reduce food waste. Although, participants are expected to be in favor of suggestions such as Social Recipes, eco-feedback was perceived as more effective. Hence, both techniques should be combined as they target wasteful behaviors in different, yet relevant ways. For example, actionable suggestions were found to be inspiring and trigger food-related conversations whereas eco-feedback with social comparison motivated users to monitor their waste more carefully. When participants were asked whether food sharing technology should include both actionable suggestions and feedback of past behaviors almost all participants (80%) agreed.

Limitations

This work has limitations. First, based on observation and users comments, the manual entry of availability seemed to be a significant stumbling block for participants which was also indicated in a previous study, where almost all participants would limit their continued use of the application after the study because of the manual method (Farr-Wharton et al., 2014). When participants were asked about their preference for the level of automation, almost all participants (i.e., 80%) preferred partial automatic food tracking to make data entry easier, but that still requires active involvements and responsibility. Other reasons participants might have a low motivation to follow social recipe suggestions could be the impracticality of getting together or they just wanted to make something else. Hence, if users were provided with more options or suggestions set by their own preferences, manual entry might become less of a problem. Second, the length of the study was too short to evaluate actual changes in behaviors or attitudes. This is why the perceived impact on awareness was evaluated and the type of reactions towards suggestions and probes rather than actual changes. Although a longer study is desirable to explore the impact on behavior change, this should be done with an improved data entry method as this was considered an obstacle. Future work should take into account these limitations. Nevertheless, providing the experience of design interventions in situ within a relevant context allows a better understanding of the constrains of the proposed concepts. It also helps in providing an understanding how technology can be leveraged to support collaborative behavior against food waste in a domestic environment through sharing.

7.5 CONCLUSION

The aim of this chapter is to contribute to an understanding how to design a community-based social (recipe) system that can be integrated in consumers daily activities for effective but pleasurable food waste prevention. Specifically, this chapter explores how Social Recipes (and the addition of eco-feedback) could impact consumers. Technology is expected to be seamlessly integrated in our daily environment, where appliances co-interact and support our food practices at home. The work presented here could be of great value for the design of future home technology in creating awareness and engagement at both household and community levels. To explore and evaluate how Social Recipes could reduce food waste, three user studies were conducted and based on the findings a number of design implications were presented. These implications mainly indicate that for a food sharing system to be accepted, users should be given options and flexibility in the nature of information they receive. This might be required to reach a broader spectrum of users and situations where food sharing could be desirable. This also entails that the method of influence should be a combination of information about past behaviors (i.e., eco-feedback) and information that is more directive (i.e., actionable suggestions such as Social Recipes). With both approaches impacting awareness differently, they should rather be seen as complementary. Hence, both competition and collaboration could be used as motivators to reduce food waste within a community, but the level to which it is effective might be different and depend on the user or situation. In the deployment study, competition seemed to be more motivating for reducing waste, while suggestions for collaborations ended up in conversations that was not perceived as effective even if it might have had impacts on food-related behaviors indirectly.

Part III.

Reflection

8 GENERAL DISCUSSION

In this final chapter, a summary is provided of the key contributions of this work and design guidelines that were extracted from all chapters for designing a community-based social system for food waste prevention. Furthermore, personal reflections are provided on the design process and the different steps of evaluation of the proposed system. This chapter further discusses limitations together with suggestions for future research. The last section covers further considerations and implications beyond this work.

8.1 CONTRIBUTIONS

The main objective in this work was to evaluate how emerging technologies could raise consumers' awareness about food waste and how it could motivate them in taking actions in domestic environments. Inspired from insights gained in various research areas such as behavioral science on food-related decision-making, sustainability research, human-computer and human-food interaction, the sharing economy, and current developments in sensing technology, an innovative community-based social system was proposed. This work is a first step in exploring the use of pervasive and persuasive technology in reducing domestic food waste from a collective approach. The main contributions of this dissertation are as follow:

1. A theory is proposed and tested on the relationship between (collective) perception, pro-environmental motives and the adoption of sustainable behaviors.
2. A community-based social system is proposed with an innovative concept for food sharing (i.e., Social Recipes).
3. And as part of this community-based system, this work has shown the significance of providing eco-feedback of wasted foods (i.e., E-COmate).

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4. In testing these two concepts or elements (i.e., Social Recipes and E-COmate) of the overall system, prototypes has been build and evaluated in user studies to explore its impacts on awareness and engagements.
5. Findings from these studies informed implications for the design of the overall system. These implications can be used as general design guidelines (which are discussed next) for more effective future domestic food waste-related technologies in motivating consumers to reduce food waste.

This dissertation contains personal contributions to the definition and redefinition of the problem statement, research goal and approach. This includes the preparation of procedures and protocols for user studies, the selection of research participants and materials, survey design, experimental design, data collection and analysis. This dissertation further contains personal contributions to the development of the prototypes with regard to conceptualization, user interface prototyping and design, specifications, system requirements, and deployments. The prototypes were build in support and by members of the supervising team, a project partner, and technical and student assistants.

8.2 DESIGN GUIDELINES

These contributions aims at reducing the impact of food waste on the environment, which has called for critical attention. Current developments in technology and its future prospective has shown opportunities that could be leveraged to reduce food waste from a collective point of view. This work explored how technology could be utilized in reducing food waste at the community level. Based on findings from the user studies, the following design considerations are suggested for further developments of the proposed community-based social system and in designing future domestic food-waste related technologies in general:

1. *Sustainable food-related technology should include both feedback information and actionable suggestions to support consumers in reducing food waste.* Both influence strategies should be considered as they target wasteful behaviors in different, yet relevant ways. Findings in *Chapter 5* showed that group feedback (i.e., without negative social comparison information) reduced food waste, raised awareness and had impacts at moments of disposal and the way participants do groceries. It was also seen as providing insights on a direction for future behavior, especially when it contains details on the types of waste and the time of wastage. Moreover, in *Chapter 7* feedback was perceived as more effective for reducing food waste than actionable suggestions alone. Although, participants have also indicated the importance of receiving additional suggestions such as recipe tips. Accordingly, findings showed that Social Recipes triggered conversations and were used as

inspirations for other recipe ideas: this might indirectly impact food waste.

2. *Feedback information applied to food waste should be provided constantly as a reminder of wasteful behaviors, while also available at the background for daily reflections.* E-COmate helped in raising awareness and understanding of food waste behaviors because of the perceptual connection it creates towards the disposed items and the choices that led to it. Because of the variety of items that are disposed on a daily basis and the variety of reasons related to it, feedback should be immediate. For example, feedback could be provided immediately after disposal so that consumers' can directly assign the feedback information to the relevant behavior and thence, get a better understanding of their individual impact. Immediacy of feedback has been acknowledged in previous research: it is usually more effective in promoting learning than delayed feedback (Chickering and Gamson, 1987).

3. *Feedback of wasted foods should combine the use of metaphors with accurate and specific (e.g., temporal) information. The latter could support consumers better in understanding and tracing back their waste and related reasons.* For example, details should be provided on how food waste amounts are calculated, the composition of the waste content (such as edibles vs. inedibles), and the moment or time of disposal. This would be necessary to gain consumers trust in the technology, which could in turn impact its effectiveness. Moreover when a specific measurement is used such as kilograms opposed to servings or meals, it would leave space for individual interpretation (e.g., as 200 grams of meat could be considered as one serving by one person *or* 2 servings by another person). However, this preference was not hold by all participants. Thence, a combination of measurement units should be used to meet the needs of all consumers (for example the number of meals as well as the weight).

4. *Feedback information should include a combination of economical incentives, self-comparison, and social-comparison as additional motivators to reduce food waste.* Participants' showed interest in the economical impact, which might be specific for the selected target group being mostly students. Another reason for this preference might be the high food costs relatively to other expenses such as water and electricity: previous findings showed that monetary incentives were not necessarily motivators for reducing energy consumption because of the low costs (Delmas et al., 2013). Moreover, social comparison was an important aspect motivating participants to monitor their waste more carefully. Findings in *Chapter 5* and 7 showed the importance of a green competition. Overall, comparison information should be combined with economical incentives to provide consumers knowledge on how they are doing relatively.

5. *Sustainable food-related technology for food sharing such as with the concept of Social Recipes, should consider spatial information and minimize travel distance.* Consumers might find the distances inconvenient, which likely prevents them from sharing. Thence, food-sharing technology should always consider spatial information to make sharing more attractive and easy. In the case of Social Recipes, the system could for example consider ingredients from users who are located not much further than the closest supermarket. Other solutions would be to minimize the distance to be traveled by all users, provide recipe options based on travel distances, or show how much someone would save (i.e., the gains in cost) if one chooses to share.

6. *Sustainable food-related technology for food sharing should carefully implement trust mechanisms.* Trust was considered critical for the acceptance of food sharing technology. This could be done through personal benefits such as healthy foods or consumer similarities. In the case for Social Recipes, the consideration of healthy food is expected to have great additional impacts (e.g., less meat is considered healthier and would reduce land use) on sustainability than reducing food waste alone (Rutten, 2013). Moreover, by providing sharing suggestions that are based on items users like might increase interest and hence the likelihood of acceptance (i.e., through recommender systems). Users could be connected with friends or with others who share similar tastes or food interests to improve their trust.

7. *Sustainable food-related technology for food sharing should aim at supporting the exchange of information between users that could bridge connections among users or serve as a mechanism for inspiration and knowledge gain.* Previous research have shown that the social environment has a valuable input for food-related decision-making as people can easily adopt, imitate or learn from others (Contento, 2010). Technology could take a mediating role in this. Accordingly, findings in *Chapter 7* showed that Social Recipe suggestions initiated topics for conversation even though the recipes were not actually made nor had impacts on coordination among participants.

8. *Sustainable food-related technology for food sharing should give users options and flexibility in the nature of information they receive to reach a broad spectrum of users and situations where food sharing could be desirable.* For example in the case for Social Recipes, users should be provided with the option to set the frequency of suggestions, food preferences, and the users for sharing. Furthermore, users could also just receive a simple reminder that their ingredients are sufficient for certain recipes that are available in the database so that they can further select whether they like a new way of cooking such as by selecting Social Recipes.

9. *Finally, sustainable food-related technology for food sharing as well as eco-feedback should leave space for self-reflection so that consumers can decide to what extend technology can have an impact.* Based on the findings discussed in the *Chapters 5, 6 and 7*, technology aiming at motivating sustainable behaviors should find the right balance in the level of presence (e.g., at the background, and yet responsive) that could catch users attention on a daily basis without being too pervasive.

8.3 REFLECTIONS

8.3.1 Part 1: Envisioning

This section reflects on the process that was taken leading to the design guidelines discussed above. This process of evaluation of the proposed community-based social system and innovative concepts started (i.e., described in *Chapter 2*) with determining the main contributors, the most common food waste types, and the most common reasons of wastage. This provided information on *who* to target, *what* to target and *how* food waste could be targeted more effectively. As a specific target group (*who*) was chosen in this work, findings should not be generalized directly to other types of consumers. Although this could be considered a limitation, it is also an advantage; consumers relations with foods are complex, which should not be generalized. By narrowing down the target group, a deeper understanding could be gained in the specific needs of the group, which was suggested by Wrap (2014). Moreover, the participants recruited in this work were not necessarily sustainable, were considered to have busy lifestyles and were not specifically interested in sustainable technology. Hence, participants in this work might not be using sustainable food-related technology on a voluntary basis for the purpose of sustainability. Therefore, in targeting this audience, implementation might need to be enforced or incentives such as costs or social activity should be more emphasized rather than sustainability alone. Furthermore, this work focuses on specific food types (i.e., perishables), which does not entail the irrelevance of other food types (*what*). Bread and dairy were often reported as commonly wasted (in *Chapter 5*), but did not receive full attention in *Chapter 7*. Based on the focus on perishables, the proposed solutions cannot be generalized to other food types. Moreover, the proposed solutions (*how*) might not always be necessary or desirable for the purpose of reducing food waste. For example, there are also non-technological solutions with a collective approach that might be more preferable for certain consumers (e.g., a food sharing group on Facebook). Furthermore, the bottom-up approach that is taken in this work requires support from top-town approaches. Hence, other approaches should be considered equally important to deal with the complex issue of food waste. One important and unique aspect of this work is the collective approach and the focus on the community rather than the individual. As part of this collective approach, an experimental study was conducted on perception that could be fundamentally biased towards a more global or collective perception style depending on the level of sustainable behaviors a consumer adopt (*Chapter 3*). With previous research showing that perception style depends on our environment and its level in emphasizing interdependence (Colzato et al, 2010; 2008), the link between perception style and sustainable behaviors could provide a premise to present information in such a way it emphasizes interdependence (i.e., social relations). Although, further research is necessary before a fundamental statement could be made on how to design for sustainability, this work introduces concepts/solutions displaying information that supports the perception of interdependence. Hence, the proposed concepts/solutions and guidelines are designed specifically for a certain group of consumers, a specific group of food waste types, and in a specific manner, leaving space for other direction for research and approaches that could still be within the scope of this work.

8.3.2 Part 2: Explorations

The second part of this work first described the development of technological probes for E-COmate, the first concept introduced as part of the community-based social system (i.e., in *Chapter 4*). Although, this concept is based on eco-feedback that is normally applied to consumption that can be easily measured such as energy, water, or fuel, it should be noted that food waste cannot be measured as easy. Research should also focus on how to measure it in parallel to exploring ways to use the information: knowing how information can be motivating for consumers in adopting sustainable behaviors, could inform to what level food waste should be measured. Accordingly, E-COmate was deployed in a student residence to explore its impact on food waste patterns, awareness, and engagements (i.e., in *Chapter 5*). Data was collected through a combination of visual inspections, semi-structured interviews, and a questionnaire. Findings from this deployment showed the potential of feedback as a means for improving awareness and to motivate active engagements. Moreover, findings showed which design aspects participants found effective (i.e., interactivity, specificity and the use of social influence strategies such as comparison information). These design aspect were further validated in an evaluation of more detailed and potential display visualizations (i.e., in *Chapter 6*). These findings informed on the level to which technology should be able to monitor food waste. Finally, technological probes were developed to evaluate the Social Recipes, the second concept that could be part of the community-based social system. With this concept, the intention was to work towards designing for action through feed forward (i.e., an opposite strategy from E-COmate). Initially, Social Recipes were positively evaluated with expected influences on awareness, knowledge, coordination, surprise and connectedness. However, when the concept was deployed and evaluated in a Wizard of Oz user study, impacts were found only on awareness and knowledge. Surprisingly, Social Recipes were not considered effective for reducing food waste as opposed to E-COmate but was considered desirable to have in addition to feedback information. Hence, so far, it seem to be highly relevant to include both feedback and feed forward as influence strategies.

8.4 limitations and future work

This work has limitations. First of all, behavior change was not explored. Behavior change was not claimed in any of the studies discussed. Instead, findings mainly provide insights into how the prototypes have impacted awareness and behaviors in response to interventions: the interventions might or might not have lead to long term impacts on behavior. In order to study behavior change, longer studies are required with a more extensive sample size and diversity. Instead, the proposed system serves as a frequent reminder to support a goal (e.g., nobody like to waste) and potentially break habits and create new ones through repetition and automaticity (de Vries et al., 2011). The studies presented here shed light on how habits might change and what design aspects should be considered in designing and developing a more effective system than what is currently available. In future studies, different types of households, such as families with or without children, and community houses should be recruited. Research could also explore larger social network of different types. Rather than independent households, research could target a number of households that are related to each other (e.g., friends, families or neighbors). This could extend to a whole town or city.

With regard to the length of the studies, it is unclear what is required as most sustainability research evaluate interventions for 1 to 3 months (Brynjarsdóttir, 2012). Additionally, more advanced prototypes should be developed with easier data entry before the proposed concepts can be evaluated in longer user studies. An advanced prototype or even a final system should be deployed with an interface that is easy to use to stimulate natural interactions. In this work, deployments were done with prototypes that needed rebooting or where the intelligence of the systems was simulated. For example, for Social Recipes, mobile applications were used to test out interactions, while in the future, fully connected home appliances could co-interact (build-in applications such as in the fridge or the bin) and support sustainable lifestyles. Instead, the mobile application was used to replace future build-in applications.

Also, the prototypes used in this work might not have captured all wasted foods or availability. Although, this work mainly focuses on the impacts of the concepts to find implications for further design, the effectiveness or desirability of the concepts might highly depend on what it can capture. This was a major methodological and technological challenge. For example, suggestions might not have been based on all available ingredients and feedback might not have been based on all wasted foods. Consumers might need incentives to enter food availability or to use the bin properly. At the same time they might also need to enter food availability or use the smart bin properly to receive these incentives. Easy and accurate food (waste) logging and tracking is not only relevant for better suggestions, visualizations, and evaluation of the concepts, it is also necessary to better understand reasons of food waste so that influence strategies could target more specific behaviors. Future developments such as in sensor technology or image recognition is expected to significantly improve the logging and tracking of food or food waste items.

Another limitation this work could be subject to is the Hawthorne effect, a type of reactivity in which individuals, in any human-centered study, modify or improve an aspect of their behavior in response to their awareness of being observed. So the question in this dissertation would be how the conducted users studies actually reflected real system usage? The Hawthorne Effect was reported by Mayo (2004, as discussed by Macefield, 2007) who investigated methods of increasing productivity in an Electrical Company during the 1920s and 30s. The finding of interest was that no matter what change was introduced to working conditions, the result was increased productivity because of the novelty of the situation and the increase in attention they received. Related to the Hawthorne effect, a possible limitation in the deployments/user studies conducted for this dissertation is that participants could have easily identified the differences between the different conditions (i.e., intervention vs control group, baseline vs. intervention measure, no social comparison information vs. comparison information). Hence, it was very likely and easy for them to know which interface is expected to give the better performance. However, several experimental design choices were made that might defend against the Hawthorn effect. For example, the use of qualitative techniques, such as baseline and post-measurements, allowed to distinguish levels of change within subjects. Moreover, semi-structured interviews for retrospection allowed gathering evidence of reasons that might have brought the quantitative results other than the Hawthorne effect. In general, there are many other ways in which the adopted user studies in this dissertation are significantly different from the original Hawthorne studies as discussed by Macefield (2007). First, the context and behavior of interest were different: home vs. work environment and a more complex behavior vs. a more simple repetitive task. Second, in the original Hawthorne studies, participants were experts while the participants discussed here, although very experienced around food and food waste, have different levels of expertise in being sustainable, which further depends on many other factors. Third, the metrics of interest differ. In the Hawthorne studies, efficiency was the main measurement, whereas in this work it was also about *how* participants interacted with the system and with others to inform on its design.

Finally, opposed to the workers in the original studies, the participants here may not have had a personal interest in a successful outcome of the study.

A final limitation to discuss is that the perception study described in *Chapter 3* requires replication studies. Different perception tests should be adopted with different types of participants to confirm the link between perception and sustainable behaviors. As soon this link is confirmed in lab studies (the link between the level of interdependence in an environment and perception is already confirmed), an intervention with the proposed system could be evaluated for its impact on behaviors as well as perception. Future work should also include observed rather than self-reported behavior as research has noted the limitations of using self-reports on environmental attitudes and behaviors (Bratt, 1999). Observed behavior, for example, could be wasted foods, actual energy consumption or other resources. Participants, for example, could be assigned to a sustainable vs. a non-sustainable group by comparing their consumption patterns with an average for more grounding results.

8.5 BEYOND THIS WORK

Beyond this work, some other implications should be discussed. First, there is a need to stress the role of society in trusting and accepting domestic food-related technology for sustainability. A community-based system with the aim at supporting (collective) awareness and food sharing touches a very personal side of our lives. Any attempt to changing them is a challenging task. For this reason, technology should require low effort from users, while highlighting actions that are socially and economically appealing and acceptable. For example, if consumers could be motivated in reducing their food purchases (as a way to prevent food waste), money could be spend on other things, which would increase welfare (Rutten, 2013). But this is only hypothetical. Without reliable and solid data, policy makers have insufficient basis for introducing policy changes. Hence, the question remain on how societies could be motivated to participate in longitudinal studies that allows researchers to evaluate how sustainable food-related technology could have an impact, for example, on the economy.

Another implication is how to balance health benefit vs. the goal of reducing food waste. Sustainable choices might not always entail healthy alternatives. On the other hand, according to Rutten (2013), a healthy choice is equal to a sustainable choice. She claims that it is better to accompany domestic food waste reductions with behavior changes towards a healthy diet as it costs less in terms of GDP and it requires less land. In the case of Social Recipes, for example, this would mean that suggestions should take into consideration a variety of food intake. Moreover, it could systematically reduce dairy and meat suggestions. These design implications should be considered equally important as the prevention of food waste.

Furthermore, privacy should be taken into account. Privacy is an aspect that might deter consumers from using a system as proposed in this work. Technology that tracks in-home food availability and waste pervasively, and turn visualizes this to other users, could expose private matters. The information could also be a target for taxes, insurances, health inspections, child welfare etc. Therefore, an optimum balance should be found in supporting sustainable food practices and consumers' privacy.

To understand how consumers are driven by these aspects, interdisciplinary research is necessary. The complexity of these implications shows a need for integrated collaboration between behavioral scientists, engineers, interaction designers, economists, and nutritionists in developing food-related technologies for sustainability, as well as media to get the word spread out. In general, researchers should make better use of knowledge from outside their fields that has major relevance for food-related sustainability research. The main long term challenge within the scope of this work would be to explore the effects of application-mediated interventions on consumers perceptions, values, behaviors, our economy as well as our environment. In the end, an interesting question is whether food could become a common good within a community where technology could change peoples' mindsets and prevent food waste on a global scale.

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LIST OF FIGURES

1 http://westhouse.sfu.ca/
2 http://smartdesignworldwide.com/work/ford-smart-gauge/

LIST OF TABLES

A KAISER'S GENERAL ECOLOGICAL BEHAVIOR QUESTIONNAIRE

The conservation behaviors grouped into seven performance domains:

Energy conservation
1. I own energy efficient household devices
2. I wait until I have a full load before doing laundry
3. I wash dirty clothes without prewashing
4. In hotels, I have the towels changed daily
5. I use a clothes dryer
6. I bought solar panels to produce energy
7. I use renewable energy sources
8. In the winter, I keep the heat on so that I do not have to wear a sweater
9. In the winter, I leave the windows open for long periods of time to let in fresh air
10. In winter, I turn down the heat when I leave my apartment for more than 4 h
11. I prefer to shower rather than to take a bath

Mobility and transportation
12. I drive my car in or into the city
13. I drive on freeways at speeds under 62.5 mph
14. I keep the engine running while waiting in front of a railroad crossing or in a traffic jam
15. At red traffic lights, I keep the engine running
16. I drive to where I want to start my hikes
17. I refrain from owning a car
18. I am a member of a carpool
19. I drive in such a way as to keep my fuel consumption as low as possible
20. I own a fuel-efficient automobile (less than 7 liters per 100 km)

21. For longer journeys (more than 6 h), I take an airplane
22. In nearby areas (around 30 km), I use
public transportation or ride a bike
23. I ride a bicycle or take public transportation to work or school

Waste avoidance
24. I buy milk in returnable bottles
25. If I am offered a plastic bag in a store, I take it
26. I reuse my shopping bags
27. I buy beverages in cans
28. I buy products in refillable packages
*51. I tend to overbuy food that get wasted
*52. Past food date is a common reason for throwing out food
*53. Forgetting leftovers is a common reason for throwing out food

Consumerism
29. I use fabric softener with my laundry
30. I use an oven cleansing spray to clean my oven
31. I kill insects with a chemical insecticide
32. I use a chemical air freshener in my bathroom
33. I buy convenience food
34. I buy seasonal products
35. I buy bleaches and colored toilet paper
36. I buy meat and products with eco-labels
37. I buy domestically grown wooden furniture
*54. I am a vegetarian
*55. Sometimes I don't mind eating vegetarian
*56. I want to reduce my meat consumption

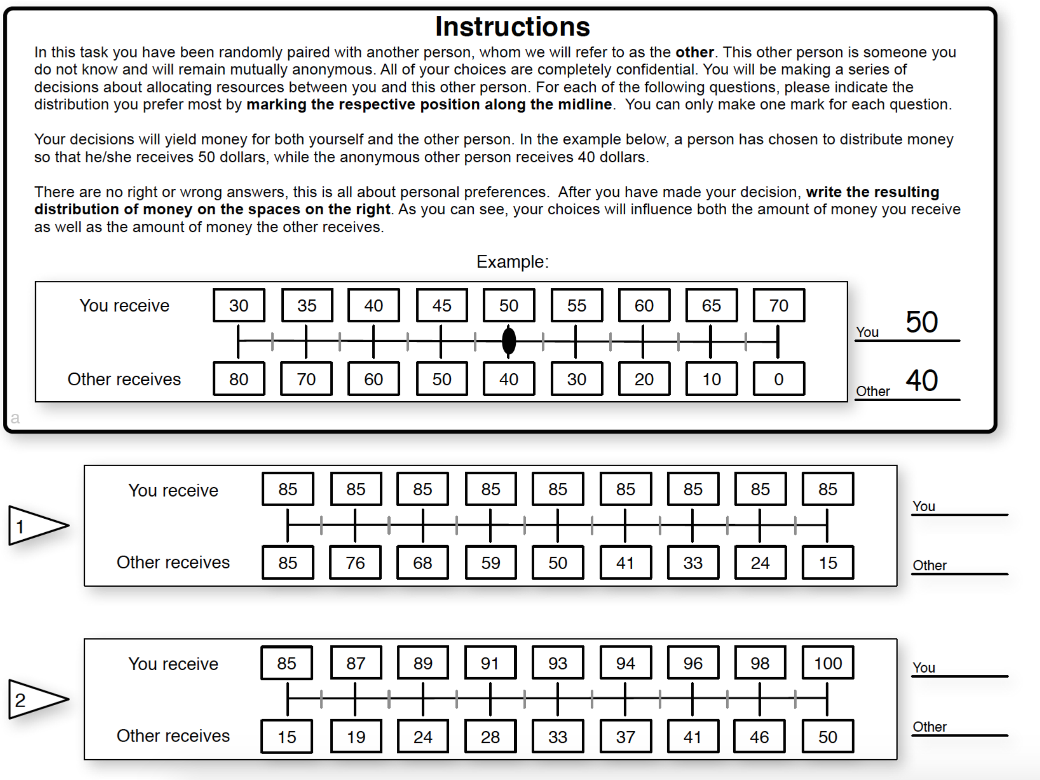
Recycling
38. I collect and recycle used paper
39. I bring empty bottles to a recycling bin
40. I put dead batteries in the garbage
41. After meals, I dispose of leftovers in the toilet

Vicarious, social behaviors towards conservation
42. After a picnic, I leave the place clean as it was originally
43. I am a member of an environmental organization
44. I read about environmental issues
45. I contribute financially to environmental organizations
46. I talk with friends about problems related to the environment
47. I have pointed out unecological behavior to someone
48. I boycott companies with an unecological background
49. I have already looked into pros and cons of having a

private source of solar power
50. I requested an estimate on having solar power installed

B MURPHY'S SOCIAL VALUE ORIENTATION MEASURE

Paper based SVO instructions and 2 item examples that were used in the online experiment:



Instructions

In this task you have been randomly paired with another person, whom we will refer to as the **other**. This other person is someone you do not know and will remain mutually anonymous. All of your choices are completely confidential. You will be making a series of decisions about allocating resources between you and this other person. For each of the following questions, please indicate the distribution you prefer most by **marking the respective position along the midline**. You can only make one mark for each question.

Your decisions will yield money for both yourself and the other person. In the example below, a person has chosen to distribute money so that he/she receives 50 dollars, while the anonymous other person receives 40 dollars.

There are no right or wrong answers, this is all about personal preferences. After you have made your decision, **write the resulting distribution of money on the spaces on the right**. As you can see, your choices will influence both the amount of money you receive as well as the amount of money the other receives.

Example:

You receive	30	35	40	45	50	55	60	65	70
Other receives	80	70	60	50	40	30	20	10	0

You 50

Other 40

a

1

You receive	85	85	85	85	85	85	85	85	85
Other receives	85	76	68	59	50	41	33	24	15

You ______

Other ______

2

You receive	85	87	89	91	93	94	96	98	100
Other receives	15	19	24	28	33	37	41	46	50

You ______

Other ______

C QUESTIONNAIRE 1

1. How does the bin system influence your personal behavior?

Influence on individual behavior regarding food and planning.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on individual behavior regarding purchasing.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on individual behavior regarding food preparation.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on individual behavior regarding dealing with leftovers.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

---

2. How does the bin system influence the behavior of you and your house mates overall?

Influence on the overall behavior in your house regarding food and planning.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on the overall behavior in your house regarding purchasing.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on the overall behavior in your house regarding food preparation.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

Influence on the overall behavior in your house regarding dealing with leftovers.

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

---

3. How does the bin system effect awareness on overall food practices?

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

4. How much is your level of motivation to change your behavior around food practices at this point?

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

5. Does the bin system support reflection?

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

6. Is the bin system usable?

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

7. How do you feel about using the bin system?

Very much	Somewhat	Undecided	Not really	Not at all
5	4	3	2	1

D QUESTIONNAIRE 2

Age:

Gender

1. Male 2. Female

I do groceries..

1. Once a week
2. 2-3 times a week
3. 4-5 times a week
4. Almost every day
5. Other:

I cook..

1. Once a week
2. 2-3 times a week
3. 4-5 times a week
4. Almost every day
5. Other:

I tend to overbuy food that get wasted.

1. Strongly Agree
2. Agree
3. Undecided
4. Disagree
5. Strongly Disagree

I commonly throw out food because of passing expiry dates.

1. Strongly Agree
2. Agree
3. Undecided
4. Disagree

5. Strongly Disagree

I commonly throw away leftovers that I forgot I have.
1. Strongly Agree
2. Agree
3. Undecided
4. Disagree
5. Strongly Disagree

The food commodity I throw out most often are:
1. Meat and Fish
2. Vegetables and Fruits
3. Grains and Starches
4. Other:

On a weekly basis, I think I throw away (in kilograms):

On a weekly basis, I think I throw away (in number of servings):
A serving is a quantity of food suitable for or served to one person.

On a weekly basis, I think I throw away the following amount of water necessary for the production of the food I have wasted (in liters):

I think, in comparison to other students in McCow my food waste is:
1. Much higher
2. Higher
3. About the same
4. Lower
5. Much lower

My level of interest in actively saving food from being wasted is:
1. Not at all interested
2. Not very interested
3. Neutral
4. Somewhat interested
5. Very interested

My level of concern in the issue of food waste in relation to global food security:
Food security is the the state of having reliable access to a sufficient quantity of affordable, nutritious food.
1. Not at all concerned
2. Not very concerned
3. Neutral
4. Somewhat concerned

5. Very concerned

I would adopt technology in a home setting to raise awareness on my food waste practices.
1. Not at all likely
2. Not very likely
3. Undecided
4. Somewhat likely
5. Very likely

The main reason for me to prevent food waste is:

What is your floor number? *
Please provide the kitchen number you mainly use (i.e., 209, 229, 241, 309, 329, 341, 409, 429 or 441)

Any comments or suggestions on the prototype (bin and tablet visualisation) that was installed in your kitchen?
Furthermore, how did it impact your thoughts about food waste or your food practices (e.g., food planning, doing groceries, food preparation or dealing with leftovers)? Answer only if you use kitchens 209, 229, 241, or 309.

E FOOD WASTE DATA FROM THE VISUAL INSPECTIONS

Audit nr	Date	Group	Vegs & fruits	Meat & fish	Grains & starches	Contamination	Other compost	Inedibles
1	15/2/16	I	88	212	144	270	228	0
1	15/2/16	C	138	0	24	34	122	0
1	15/2/16	C	2210	244	202	220	652	456
1	15/2/16	I	20	0	80	0	18	18
1	15/2/16	C	882	0	12	0	32	12
1	15/2/16	C	858	0	0	18	200	140
1	15/2/16	I	1510	0	518	6	1082	0
1	15/2/16	I	588	0	234	18	130	0
1	15/2/16	C	538	38	410	52	146	148
2	17/2/16	I	974	0	224	0	1156	296
2	17/2/16	C	226	0	0	66	60	22
2	17/2/16	C	0	0	0	94	270	218
2	17/2/16	I	176	0	0	74	92	252
2	17/2/16	I	10	0	1324	24	150	32
2	17/2/16	C	164	0	0	0	68	96
2	17/2/16	C	4	6	0	0	168	78
2	17/2/16	C	94	0	0	76	142	16
2	17/2/16	I	80	14	346	0	62	388
3	22/2/16	I	266	90	984	82	180	148
3	22/2/16	C	972	324	143	258	108	208
3	22/2/16	I	938	0	0	160	172	638
3	22/2/16	C	0	0	40	0	42	116
3	22/2/16	C	934	194	422	4	306	284
3	22/2/16	I	234	58	1028	12	298	2184
3	22/2/16	C	213	104	173	170	3	902
3	22/2/16	C	213	104	173	170	3	902
3	22/2/16	I	0	0	0	28	98	360

Audit nr	Date	Group	Vegs & fruits	Meat & fish	Grains & starches	Contamination	Other compost	Inedibles
4	24/2/16	I	1476	1524	758	0	12	0
4	24/2/16	C	0	0	0	40	146	322
4	24/2/16	C	124	0	0	0	158	1142
4	24/2/16	C	22	0	0	0	128	102
4	24/2/16	C	72	138	144	50	184	268
4	24/2/16	C	472	438	484	0	436	30
4	24/2/16	I	332	0	0	0	152	0
4	24/2/16	I	238	190	380	8	176	662
4	24/2/16	I	260	0	42	12	54	144
5	29/2/16	C	18	0	244	312	558	4
5	29/2/16	I	80	0	166	20	234	694
5	29/2/16	C	438	234	140	24	264	76
5	29/2/16	I	74	0	126	0	196	80
5	29/2/16	I	0	0	0	58	20	204
5	29/2/16	I	230	0	132	58	334	210
5	29/2/16	C	114	0	632	124	154	310
5	29/2/16	C	84	0	0	0	54	282
5	29/2/16	C	400	0	0	0	198	58
6	2/3/16	I	0	802	162	68	38	146
6	2/3/16	C	0	0	36	0	144	682
6	2/3/16	I	200	0	106	0	264	1522
6	2/3/16	I	582	0	690	16	72	514
6	2/3/16	C	0	30	412	0	196	566
6	2/3/16	C	0	40	68	0	12	0
6	2/3/16	I	0	0	100	0	30	4
6	2/3/16	C	496	22	30	22	284	850
6	2/3/16	C	410	340	420	276	350	56
7	7/3/16	C	0	0	212	12	182	26
7	7/3/16	I	100	0	0	0	28	64
7	7/3/16	C	394	118	4	200	100	64
7	7/3/16	I	138	0	0	8	96	318
7	7/3/16	C	3030	0	174	14	388	96
7	7/3/16	C	72	0	1246	0	20	98
7	7/3/16	I	20	0	388	12	42	258
7	7/3/16	I	1502	0	0	12	518	26
7	7/3/16	C	68	212	718	142	422	262
8	9/3/16	C	0	0	0	0	68	34
8	9/3/16	C	114	370	0	28	188	120
8	9/3/16	C	1360	0	26	56	136	284
8	9/3/16	C	2816	0	328	0	134	0
8	9/3/16	I	144	0	0	0	42	52
8	9/3/16	I	246	0	10	16	182	244
8	9/3/16	I	2006	32	0	74	344	256
8	9/3/16	C	440	266	0	0	270	32
8	9/3/16	I	260	0	1416	6	0	92

Audit nr	Date	Group	Vegs & fruits	Meat & fish	Grains & starches	Contamination	Other compost	Inedibles
9	14/3/16	C	592	0	192	38	176	82
9	14/3/16	I	120	0	0	6	48	176
9	14/3/16	I	128	0	420	0	282	532
9	14/3/16	C	192	38	0	4	56	148
9	14/3/16	C	1180	0	150	0	268	208
9	14/3/16	C	554	0	438	6	308	8
9	14/3/16	C	566	0	494	0	218	520
9	14/3/16	I	14	176	66	186	146	390
9	14/3/16	I	0	0	438	18	50	12
10	16/3/16	I	668	0	292	732	0	148
10	16/3/16	C	14	0	78	42	146	298
10	16/3/16	C	0	0	0	84	0	40
10	16/3/16	C	76	106	40	30	128	428
10	16/3/16	C	1528	244	270	8	420	368
10	16/3/16	I	82	0	10	0	24	164
10	16/3/16	I	264	0	576	14	152	1196
10	16/3/16	I	292	0	16	6	116	180
10	16/3/16	C	502	0	452	4	146	104
11	21/3/16	I	398	0	0	0	168	206
11	21/3/16	I	128	0	768	0	38	112
11	21/3/16	I	570	0	578	0	196	314
11	21/3/16	I	40	0	964	0	106	16
11	21/3/16	C	890	0	306	216	56	176
11	21/3/16	C	260	420	242	260	242	384
11	21/3/16	C	90	0	30	4	128	148
11	21/3/16	C	82	380	136	326	152	314
11	21/3/16	C	0	0	402	128	76	4
12	23/3/16	C	274	0	0	18	134	384
12	23/3/16	C	0	0	0	0	46	32
12	23/3/16	C	16	232	1570	66	80	144
12	23/3/16	I	186	0	56	2	90	456
12	23/3/16	I	6	20	0	60	58	516
12	23/3/16	I	580	0	0	0	194	110
12	23/3/16	I	114	0	180	40	334	798
12	23/3/16	C	20	0	98	154	520	564
12	23/3/16	C	12	0	56	54	190	438
13	28/3/16	C	244	0	0	42	168	210
13	28/3/16	C	0	152	0	0	396	138
13	28/3/16	I	0	0	0	0	4	230
13	28/3/16	I	132	0	0	52	80	364
13	28/3/16	C	254	126	268	210	176	254
13	28/3/16	C	114	0	6	2	160	352
13	28/3/16	I	62	932	914	0	24	122
13	28/3/16	C	138	26	30	0	148	322
13	28/3/16	I	146	0	364	0	308	320

Audit nr	Date	Group	Vegs & fruits	Meat & fish	Grains & starches	Contamination	Other compost	Inedibles
14	30/3/16	C	122	0	0	0	46	166
14	30/3/16	C	0	0	0	0	56	98
14	30/3/16	C	48	128	102	0	262	966
14	30/3/16	I	0	0	284	0	116	280
14	30/3/16	C	194	0	0	10	92	400
14	30/3/16	I	0	0	0	6	82	656
14	30/3/16	I	90	0	0	8	332	1048
14	30/3/16	C	286	0	474	12	290	700
14	30/3/16	I	78	0	1428	286	204	404
15	4/4/16	C	388	0	600	100	134	692
15	4/4/16	I	0	0	50	16	8	200
15	4/4/16	I	238	0	0	0	108	640
15	4/4/16	C	98	0	346	54	88	120
15	4/4/16	I	40	0	204	0	4	242
15	4/4/16	C	6	0	72	30	164	320
15	4/4/16	C	512	470	796	40	262	304
15	4/4/16	C	416	0	0	0	160	60
15	4/4/16	I	1826	0	2627	50	808	678
16	4/4/16	C	0	0	0	58	110	98
16	6/4/16	I	84	88	764	8	62	194
16	6/4/16	C	316	690	586	0	244	806
16	6/4/16	C	40	0	0	0	60	78
16	6/4/16	C	1916	0	192	22	198	66
16	6/4/16	C	268	624	554	450	196	104
16	6/4/16	I	284	312	252	4	94	666
16	6/4/16	I	88	0	92	0	108	222
16	6/4/16	I	0	0	16	0	8	132
17	11/4/16	C	32	0	20	0	38	8
17	11/4/16	I	0	0	0	0	74	550
17	11/4/16	C	0	0	0	0	56	236
17	11/4/16	C	8	0	0	0	32	68
17	11/4/16	I	400	0	128	42	166	234
17	11/4/16	C	540	0	432	0	202	458
17	11/4/16	C	76	0	1004	654	244	0
17	11/4/16	I	130	0	1142	18	484	2608
17	11/4/16	I	62	0	1268	0	16	364
18	13/4/16	C	42	26	166	12	128	62
18	13/4/16	C	100	0	0	20	0	74
18	13/4/16	C	0	0	186	0	178	12
18	13/4/16	I	0	0	0	0	18	110
18	13/4/16	I	52	0	0	0	12	302
18	13/4/16	C	70	0	432	18	68	202
18	13/4/16	I	86	0	0	142	24	246
18	13/4/16	C	614	0	442	80	232	288
18	13/4/16	I	190	146	470	12	166	304

Audit nr	Date	Group	Vegs & fruits	Meat & fish	Grains & starches	Contamination	Other compost	Inedibles
19	18/4/16	I	110	0	128	0	12	266
19	18/4/16	C	0	84	442	0	182	54
19	18/4/16	C	318	0	1012	190	1078	240
19	18/4/16	C	234	66	526	366	162	630
19	18/4/16	C	762	356	476	338	270	230
19	18/4/16	C	108	70	592	554	304	510
19	18/4/16	I	156	0	40	156	24	30
19	18/4/16	I	178	0	36	54	12	436
19	18/4/16	I	128	0	620	0	40	292
20	20/4/16	C	932	100	420	6	276	358
20	20/4/16	I	162	0	0	0	0	86
20	20/4/16	C	116	0	124	10	14	24
20	20/4/16	I	1714	294	262	4	114	310
20	20/4/16	C	392	0	584	20	158	280
20	20/4/16	C	600	254	20	206	316	504
20	20/4/16	C	492	0	786	16	40	398
20	20/4/16	I	222	0	14	6	10	1494
20	20/4/16	I	110	0	2226	82	84	26

F QUESTIONNAIRE 3

Do Social Recipe suggestions influence your individual behavior regarding food planning?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence your individual behavior regarding food purchasing?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence your individual behavior regarding food preparation?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence your individual behavior regarding dealing with leftovers?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on your individual behavior?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence the group behavior regarding food planning?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence the group behavior regarding food purchasing?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence the group behavior regarding food preparation?

Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions influence the group behavior regarding dealing with leftovers?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on the group behavior?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions affect awareness on overall food practices?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on awareness?
Not at all 1 2 3 4 5 6 7 Very much

Please explain how:

Do Social Recipe suggestions affect coordination within your group regarding overall food practices?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on coordination?
Not at all 1 2 3 4 5 6 7 Very much

Please explain how:

Do Social Recipe suggestions affect communication within your group around the topic of food?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on communication?
Not at all 1 2 3 4 5 6 7 Very much

Please explain how:

How much is your level of motivation to change your behavior around food practices at this point?
Not at all 1 2 3 4 5 6 7 Very much

Do Social Recipe suggestions support reflection?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on reflection?
Not at all 1 2 3 4 5 6 7 Very much

Are Social Recipe suggestions efficient in reducing overall food waste?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on efficiency?
Not at all 1 2 3 4 5 6 7 Very much

Do you consider Social Recipe suggestions to be effective to reduce overall food waste?
Not at all 1 2 3 4 5 6 7 Very much

Does Eco-feedback provide an additional impact on effectiveness?
Not at all 1 2 3 4 5 6 7 Very much

Which Eco-feedback display do you prefer?
1. Without social comparison
2. With social comparison

Indicate how much impact the display without social comparison had on you.
Not at all 1 2 3 4 5 6 7 Very much

Indicate how much impact the display with social comparison had on you.
Not at all 1 2 3 4 5 6 7 Very much

SUMMARY

Design Opportunities in Reducing Domestic Food Waste:
A Collective Approach

Approximately, one-third to half of all food produced globally is wasted. In developed countries, roughly half of this food waste comes from consumers. In response to this, the United Nations has set goals to raise consumer awareness and reduce food waste by 50 percent before the year 2030. In this work, the objective was to evaluate the use of emerging technologies in improving awareness of food waste in households. Two innovative conceptual system designs were introduced and evaluated. Inspired by future sensing possibilities, the central aim of these concepts was to capture in-home food availability and waste patterns and explore ways to use this information to support awareness. The methods that were used to explore the potential of these concepts are dividable into four phases of design research. In the first phase, a vision was build, which was informed by findings from literature reviews and exploratory studies involving food waste logging, semi-structured interviews and a focus group. Based on this vision, technological probes were designed and developed. In the third phase, these probes were deployed in homes to evaluate their impact and effectiveness on reducing food waste. Finally, in the last phase, quantitative and qualitative data were analyzed with implications for further design and developments of the concepts.

This PhD dissertation contains 8 chapters. In *Chapter 1*, the problem statement and research questions are presented. In *Chapter 2*, a background is provided on food waste facts. These facts were used to inform *what* and *who* emerging technologies should target: as food waste amounts were found to differ between food types and the type of consumers or households. This chapter further discusses current technological developments and trends to indicate potential directions for research, the target group, and the rationale for adopting a collective approach to reduce food waste. In *Chapter 3*, a theory is proposed and investigated in a reaction time study to provide fundamental support for the collective approach, which was expected to inform *how* emerging technologies should emphasize information: previous research showed that the way we perceive our world depends highly on whether our environment emphasizes interdependence or independence. This link would provide a premise to present information in such a way it emphasizes interdependence or social relations. In *Chapter 4*, the first concept called E-COmate is introduced. E-COmate visualizes past consumption patterns with more accessible information of food waste generated by groups of individuals. In this chapter, the process of development and design rationale of E-COmate are explained. In Chapter 5, findings from a home deployment of E-COmate are discussed. A controlled study was conducted to investigate the impacts of E-COmate on food waste patterns, awareness, engagements and social interactions in a student residence. Subsequently, in *Chapter 6*, more detailed display visualizations for E-COmate are discussed in terms of desirability and the level of motivation it could trigger. In these two chapters, data was collected through a combination of visual inspections, semi-structured interviews, and a questionnaire: findings showed the potential of feedback as a means for improving awareness and engaging users to reduce waste. Based on the findings, design implications with regard to the provision of feedback information are discussed in both chapters. In *Chapter 7*, the second concept called Social Recipes is introduced. Social Recipes aim at providing visibility for cooperation through recipe suggestions containing ingredients owned by different individuals. This concept is fundamentally different from E-COmate in terms of the timing of intervention (i.e., after vs. before a food is wasted: feedback vs. feed forward, respectively) and type of persuasion (i.e., explicitly vs. implicitly focusing on food wasted) but it is identical in emphasizing interdependence and social relations, the main approach in this dissertation. Initially, expected experiences of the concept were explored in an exploratory study with structured interviews and a focus group. To understand experiences in-situ, a home deployment was conducted using a Wizard of Oz approach. Overall, the concept of Social Recipes was positively evaluated with expected and observed impacts on awareness, knowledge, and communication, but was not perceived as effective as when feedback is provided in reducing food waste (i.e., E-COmate). Moreover, the impact was different than when feedback is provided. Therefore, both type of strategies (feedback and feed forward) should be used when developing sustainable food-related technology. In the final chapter, based on all chapters of this dissertation, general design guidelines are presented for sustainable food-related technology. *Chapter 8* further discusses the contributions of this work which are (1) a theory, proposed and tested, on the relationship between (collective) perception processes, pro-environmental motives and the adoption of sustainable behaviors, (2) the proposal of an innovative community-based social system including eco-feedback of wasted foods and a concept for food sharing (i.e., Social Recipes), (3) the development of prototypes and its evaluation in user studies to explore its impacts on awareness and engagements in a realistic setting, and (4) implications for the design of the overall system that could be used as general design guidelines for more effective future domestic food waste-related technologies in motivating consumers to reduce food waste. Although, this work contains limitations, future work should consider longer studies with a larger sample size and advancements of prototypes for more conclusive results. Overall, this work could serve as an inspiration for researchers, interaction designers, developers and consumers to further explore the use of technology in reducing domestic food waste using a collective approach.

LIST OF PUBLICATIONS

JOURNAL ARTICLES

1. Lim, V., Funk, M., Regazzoni, C., Marcenaro, L., and Rauterberg, M. (2017). Designing for action: an evaluation of Social Recipes in reducing food waste. *In International Journal for Human-Computer Studies, 100*(2017), 18 - 32.

2. Lim, V., Funk, M., and Rauterberg, M. (2017). Think globally, act sustainably: How attention is linked to ecological behavior. *In Frontiers in Psychology* (to be submitted).

3. Lim, V., Bartram, L., Funk, M., and Rauterberg, M. (2017). To Eat or Not to Eat: An evaluation of the Impact of Eco-feedback in a Student Residence. *In ACM Transactions in Computer-Human Interaction*. New York, NY: ACM Press (under review).

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1. Lim, V., Funk, M., Rauterberg, M., Marcenaro, L., and Regazzoni, C. (2015). E-COmate: What's your non-consumption? In I. Rojas, G. Joya and A. Catala (eds.), *Advances in Computational Intelligence* (pp. 486 - 499). New York, NY: Springer Publisher.

2. Lim, V., Jense, A., Janmaat, J., and Funk, M. (2014). Eco-Feedback for Non-Consumption. *In Adjunct Proceedings of the ACM International Joint Conference on Pervasive and Ubiquitous Computing* (pp. 99 - 102). New York, NY: ACM Press.

3. Lim, V., and Yalvaç, F. (2014). Household food waste prevention: How to design and evaluate technological interventions? *Paper presented at the SIGCHI HCI & Sustainability community workshop*. Toronto, Canada.

4. Yalvaç, F., Lim, V., Hu, J., Funk, M., and Rauterberg, M. (2014). Social recipe recommendation to reduce food waste. *In Extended Abstracts Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*

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5. Lim, V., Yalvaç, F., Funk, M., Hu, J., Rauterberg, M., Regazzoni, C., and Marcenaro L. (2014). Design implications for a community-based social recipe system. *In Proceedings of the World Congress on Sustainable Technologies* (pp. 19 - 26). New York, NY: IEEE.

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1. Niforatos, E., Lim, V., Vuerich, C., Langheinrich, M., and Bexheti, A. (2015). PulseCam: Biophysically Driven Life Logging. *In Adjunct Proceedings of the International Conference on Human-Computer Interaction with Mobile Devices and Services.* (pp. 1002 - 1009). New York, NY: ACM Press.

2. Chen, M., and Lim, V. (2013). Collection and Representation of Customers' Visual Attention in a Simulated Tourist Information Office. *Paper presented at the EyeTrackBehavior Conference*, Boston, MA, USA.

3. Chen, M., and Lim, V. (2013). Tracking Eyes in Service Prototyping. *In the Proceedings of the IFIP TC13 Conference on Human-Computer Interaction* (pp. 264 - 271). New York, NY: Springer Publisher.

4. Chen, M., and Lim. V. (2013). Eye Gaze and Mouse Cursor Relationship in a Debugging Task. *In HCI International, Volume 373 of the series Communications in Computer and Information Science* (pp. 468 - 472). New York, NY: Springer Publisher.

BIOGRAPHY

Veranika Lim was born on the 21st of February 1985 in Jakarta, Indonesia. After finishing her Bachelors degree in Psychology in 2006 at Leiden University in The Netherlands, she studied Cognitive Psychology (Masters of Science) and Cognitive Neuroscience (Research Master) at Leiden University. In 2007, she graduated with distinction within the Cognitive Psychology Unit, and then again in 2010 on the topic 'Dimensionality Effects on Weather Avoidance'. Her Research Master thesis was performed at and in collaboration with the Flight Deck Display Research Lab (FDDRL) at NASA, Moffett Field, USA. To gain experience in designing for interaction, she also performed extracurricular activities at the Industrial Design department at Delft University of Technology in The Netherlands from 2007 to 2009. After her graduation in 2010, she went back for an internship at the FDDRL for another semester. In 2011, she was a research assistant at the Madeira Interactive Technologies Institute and Logica Design, a collaboration between the University of Madeira, Portugal and Carnegie Mellon University, USA. In December 2012, she started her PhD project at Eindhoven University of Technology in the Netherlands. This project was also partly conducted at the University of Genova in Italy and at Simon Fraser University in Canada, of which the findings are presented in this dissertation.

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